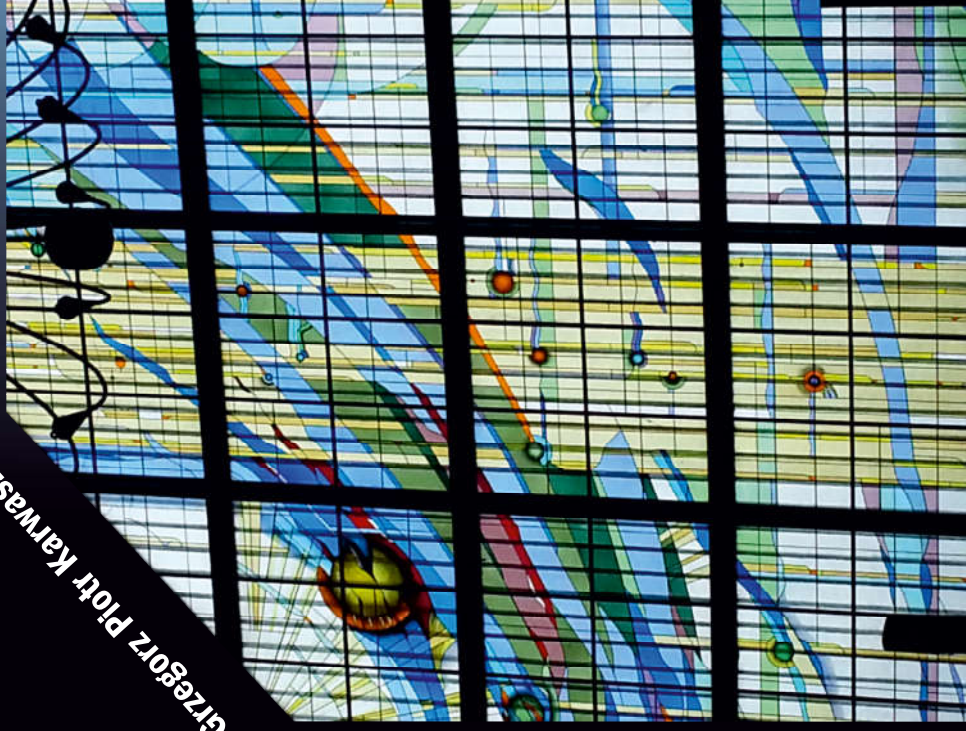


Nauka i wiara

Krótki podręcznik

Grzegorz Piotr Karwasz



Grzegorz Piotr Karwasz

Nauka i wiara. Krótki podręcznik

Dwa światy kulturowe – humanistyczny i nauk ścisłych zdają się żyć odrębnymi bytami. A poszukiwanie zamysłu Boga w przyrodzie wydaje się wręcz naruszać naukową poprawność.

W tej książce kroczymy „piątą drogą” Św. Tomasza z Akwinu, która wychodzi z samego to-li istnienia świata materialnego i porządku, który odnajdujemy w przyrodzie: „Piątą drogę wnioskujemy z regularności rzeczy”.

Naszym zadaniem jest odnalezienie, krok po kroku, tego naturalnego porządku, czyli praw przyrody (fizyki, astronomii, chemii, biologii, genetyki, antropologii), w ich szczegółowych odsłonach, by sprawdzić, czy zgodne są z Pismem. Realizujemy w ten sposób wytyczne Galileusza, który pisał, że Przyroda jest najbardziej posłuszną wykonawczynią poleceń Pana Boga.

(GK, 2023)

*I dedicate this version of the book
to the memory of
Tom McLeish*

God created man in His own image,
in the image of God created He him;
male and female created He them

Genesis, 1:27

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Premise

It seems that two cultural worlds, the humanistic and the scientific, follow separate lives: physicists disdain Aristotle and philosophers use Heisenberg to support very risky theses. Then, the nineteenth century, with a series of atheistic ideologies, decreed a rift between faith and the natural sciences¹. Seeking the divine mind in nature seems to compromise the scientific rigor.

As a kind of antidote, scientists are often cited who, although as such, i.e. rational, have been believers. In this book we show how a concord between faith and scientific thought is not a subjective opinion involving only individual scientists, but an objective one and concerns entire branches of natural sciences.

Thomas Aquinas, a doctor of the Catholic Church, begins the treatise *Summa Theologica* by indicating five "ways" for reasoning about the existence of God. Four of them are based on metaphysics: the deduction of a first, causal, essential, superior Being. The fifth way is based on the existence of nature and order in it, indeed, on the hidden end (goal?) of this natural order²:

The fifth way is deduced from the government of things. We see that some things which are devoid of knowledge, namely, physical bodies, work for an end, as is evident from the fact that they always or almost always work in the same way to attain perfection: whence it appears that they attain their end not by chance, but by a predisposition. Now that which is devoid of intelligence tends to the end only because it is directed by a knowing and intelligent being, like the arrow by the archer. There is, therefore, some intelligent being, by whom all natural things are ordained to an end: and this being we call God.

Our aim is to identify, step by step, this natural order, that is, the laws of nature (physics, astronomy, chemistry, biology, genetics, an-

¹ The rift also concerns theology and philosophy, as described in the memorable encyclical of ST. JOHN PAUL II, *Fides et ratio*, Vatican 1998.

² THOMAS AQUINAS, *Summa Teologica*, Ia, q. 2, a. 3, co., trans. Dominican Friars, Edizioni Studio Domenicano, 2014, p. 48.

thropology) in their specific details, in order to verify that they are in agreement with Scripture. Here we follow Galileo's words, according to which Nature is the most faithful observer of the divine orders.

The large number of citations, bibliographical references, illustrations and diagrams that characterize this book is aimed at following - the indications of St. Augustine, who admonished the theologian to be prepared in discourse with the mathematician (i.e., the scientist) and not to be ignorant in scientific subjects, because his incompetence can ridicule not him but the faith.

Then, the religion teacher must be no less prepared than the science teacher. That is why this manual was written, for teachers and also for their students, that is, all of us, believers or not.

Scripture and philosophy

1.1. Introduction

The "Big Bang," as scientists say, or "Creation," as the Bible says³? Adam and Eve: the first parents of the human race or just a parable with very vague meanings? The Tower of Babel or a paraphrase of a badly organized work, as we read on an Italian website?

And evolution? A heresy or "no more a mere hypothesis but a theory endowed with all the scientific characteristics", as St. John Paul II expressed it?⁴

So many questions, simple but "pungent", that must be addressed by religion teachers, even in elementary school. Have scientists discredited the Faith? No, absolutely! This is guaranteed by a full professor of Experimental Physics, professor of Physics Education at the Nicolaus Copernicus University of Toruń, who worked at the Department of Physics of the University of Trento from 1985 to 2005 and who is a scientific consultant to the European Union, the United Nations, the Republic of Korea, etc.

Present edition (29/12/2024) is a provisional English translation.

³ The lack of an agreed language is a serious problem, first and foremost for education. In September 2017, in the pages of the most prestigious American journal "Science" No. 6354, p. 880, H.S. Silva complained that in thirteen American states "intelligent design" is taught rather than a (simplified) theory of evolution. The author (GK) replied that both mere evolution and the enigmatic "intelligent design" have serious shortcomings, see the discussion in the concluding parts of the book and the answer: <http://science.sciencemag.org/content/357/6354/880.1/tab-e-letters>.

⁴ "Today, about half a century after the publication of the Encyclical, new knowledge leads us to no longer consider the theory of evolution a mere hypothesis. It is noteworthy that this theory has progressively come to the attention of researchers following a series of discoveries made in the various disciplines of knowledge. The convergence, neither sought nor provoked, of the results of the work carried out independently of each other is in itself a significant argument in favour of this theory." JOHN PAUL II, *Message of John Paul II to the Participants in the Plenary Assembly of the Pontifical Academy of Sciences*, Editrice Vaticana, 22.10.1996.

1.1.1. *These good scientists who know everything*

Science in the twentieth century has made wonderful discoveries: elementary particle accelerators reveal an infinitely small world, we communicate using invisible waves, space telescopes look at the boundaries of the universe, we study the past since the beginning of time. It seems that our knowledge has no limits, doesn't it?

Not at all! The more we know, the more the unknown opens up before our eyes. Unfortunately, scientists usually only tell about the findings, but rarely discuss the doubts that follow. As the famous Italian nuclear physicist, Prof. Antonino Zichichi, says in the book *Why Do I Believe in the One Who Made the World?*, scientists have built ivory towers, in which they have closed themselves with their knowledge. A translation from scientific language to common language is needed: a very complex work, both for the author and for the reader. Let's start from the beginning, that is, from the so-called "Big Bang".⁵ Was the world created or is it the result of a bubble of matter burst by chance?

1.2. Creation or Big Bang?

Everyone has heard of the so-called "Big-Bang", the beginning of the world. It was an immense explosion, which from a volume smaller than an orange set in motion the immense space of today's galaxies. Bang, and the whole universe was made! The book *The First Three Minutes* by Nobel Prize winner Stephen Weinberg, an agnostic-trained physicist, tells how in the blink of an eye from strange forms of primordial matter electrons⁶, protons⁷ and neutrons were formed, which

⁵ The ironic name was coined by some English astronomers, opponents of the idea that the universe had a beginning.

⁶ Electrons are the most fundamental particles that make up matter: each atom contains a specific number of them: hydrogen one, helium two, lithium three, etc. According to all theoretical and experimental indications, electrons are indivisible and very small (with a diameter of the order of 10^{-15} m). By all indications, electrons have no internal components. The electric charge of the electron is negative and constitutes the fundamental unit: no smaller charge has ever been separated in the laboratory. The electrons are very light: the old cathode ray tube TV drew the screen by brushing it with a beam of electrons deflected by a magnetic field.

⁷ Protons, 1837 times heavier than electrons (in comfortable units with the mass 911 MeV/c²), surprisingly, have about the same size, but differently they have components, which are three and are called *quarks*. The proton consists of two quarks called *up* and one *down*. However, quarks are light, *up* and *down* about 2.5 and 5.5 MeV/c², carry fractional charges

make up the entire universe today (at least so it seems). In the first three minutes, the proportions between hydrogen and helium, the two lightest gases, found in all galaxies, were defined.

Science here seems in stark contrast to the biblical account of *Genesis*, of the Creation in six days. Indeed, as a whole, the biblical "story" seems to make little sense: the formation of the Sun after that of the sky and the water? One father and one mother for all mankind? A breath that animated a clay plasma?

So many doubts that arise from the discoveries of modern sciences cast doubts on the truths of the Faith. As the then Cardinal Ratzinger wrote in 1979, it seems that in recent centuries the faith has continued to retreat to increasingly defensive positions, so that in some time there will no longer be the dogmas of the Faith to be respected⁸.

The present book aims to reverse this retreat of the Faith, but it is not a book of apologetics: it is a scientific account of physics, cosmology, genetics, linguistics that shows not only the successes of the sciences but also their limits, where science stops, leaving room for Faith. Let's start with cosmology, or rather with philosophy or even better with the book of *Genesis*. What does the Bible say, and what do the sciences (physics, mathematics, biology, anthropology, etc.) say?

The main question is as follows: is the Universe eternal or did it have a beginning? In the history of medieval universities, the discussion of the eternity of the world brought universities such as Paris and Oxford to the threshold of heresy⁹. Today we have no doubt: the universe had a beginning. But there are many topics to consider. Here is the first chapter of the Book of *Genesis*.

($+2/3$ and $-1/3$, respectively) and, according to all indications, are not separable. The life-time of the proton exceeds, according to the most recent experiments, the age of the Universe, at least a billion times; In other words: protons (and also electrons) are *stable*.

⁸ J. RATZINGER, *In the Beginning God Created Heaven and Earth. Reflections on creation and sin*, «I Pellicani» – religione, cristianesimo, spiritualità, Edizioni Lindau, Turin 2006.

⁹ The question of the eternity of the world proved essential at the dawn of modern science. As soon as the first universities were formed, in the sixties and seventies of the thirteenth century, an intellectual debate took place in various places, including Paris and Oxford, professing the eternity of the world. The bishop of Paris, Étienne Tempiere, condemned in 1277 the 210 theses that were considered heretical, including 10 on the eternity of the world. In clarifying the position of the Church, the voices of St. Thomas and St. Bonaventure were essential. For a broader discussion see e.g. P. BERNARDINI, *Eternity of the World*, University of Siena, 2007.

1.3. "In the Beginning"

¹ In the beginning God created the heavens and the earth. ² The earth was empty and desolate, darkness covered the deep, and a fierce wind blew over all the waters.

³ God said, 'Let there be light!' And the light appeared. ⁴ And God saw that the light was good, and he separated the light from the darkness. ⁵ God called the light Day, and the darkness Night. So there was evening, then there was morning: the first day.

⁶ And God said, 'Let there be a great vault separating the upper waters from the lower waters.' And so it was. ⁷ And God made a firmament, and separated the waters below from the waters above.

⁸ God called the great vault Heaven. Again there was evening, then there was morning: the second day.

⁹ God said, 'Let the waters under heaven be gathered into one place, and let the dry land appear.' And so it happened. ¹⁰ And God called the dry land the earth, and the waters called the sea. God saw how good it was.

¹¹ God said: 'Let the earth be covered with green, let it produce plants with its own seed, and let every kind of fruit tree produce its own seed!' And so it happened.

¹² The earth brought forth green grass, every kind of plant with its seed, and every kind of fruit tree with its seed. God saw how good it was.

¹³ Evening came, and morning came, the third day.

¹⁴ And God said, Let there be lights in the vault of heaven to distinguish day from night: they shall be signs for festivals, days, and years. ¹⁵ Let them shine in heaven to give light to the earth.' And so it happened.

¹⁶ And God made two great lights, the larger for the day, and the smaller for the night. And then the stars.

¹⁷ From the vault of heaven they illuminate the earth. God put them up there to rule day and night and separate light from darkness. ¹⁸ God saw how good it was.

¹⁹ Evening came, and then morning came, the fourth day.

²⁰ God said: 'Let the waters bring forth animals that dart, and over the earth and in the sky let birds fly.' ²¹ And God created the great monsters of the sea, and all that lives and darts in the waters. And God saw how good it was.

²² God blessed them, "Be fruitful, become numerous, and people the waters of the seas. And let the birds also reproduce on the earth."

²³ Evening came, and morning came, the fifth day.

²⁴ God said: 'Let the earth bring forth various kinds of animals: domestic, wild, and those that crawl.' And so it happened.

²⁵ God made these animals after their kind: the wild, the domestic, and those that crawl on the ground. And God saw how good it was.

²⁶ God said, 'Let us make man, let him be like us, let him be our image. It will have dominion over the fish of the sea, the birds of the air, the cattle, the wild animals, and those that crawl on the ground.'

²⁷ God created man like himself, he created him in the image of God, male and female he created them.

²⁸ He blessed them with these words: 'Be fruitful, become numerous, people the earth. Rule over it and have dominion over the fish of the sea, and the birds of the air, and over all the animals that move on the earth.'

²⁹ God said: 'I give you all the plants with their seed, all the fruit trees with their seed. So you will have your own food.'

³⁰ All the wild animals, all the birds of the air, and all other living things that move upon the earth will eat the tender grass.' And so it happened.

³¹ And God saw that everything he had done was really very good.

Evening came, then morning came: the sixth day.¹⁰

1.4. Shall we try to build the world?

Even by the official publishers of the Bible, such as the Palatinum in Poland, the Genesis account is commented on as a picturesque narrative, that is, not to be taken too seriously. It is advisable to interpret the story only in a theological key, as the justification of the weekly rest, and moreover to consider the contents as very distant from the real history of the universe and life in it. In fact, the "earth" that is created before the Sun and the waters separated (by no one knows what) seem to be nonsense.

What should the Genesis account be like according to common reason? In other words: shall we try to tell how the Universe should have been created? We do this interactively, with the help of drawings. What comes first? Obviously, the Sun: without the Sun there is no life. And after that? Then the earth, on which a tree grows, then the house (or a cave). Only after a man. As in the drawing below.

¹⁰ *The Bible. Interprofessional translation into current language*, Italian Church, <http://www.lachiesa.it/bibbia/tilc/index.htm> (28/01/2019). Translation from Italian (GK). We note extreme difficulty in finding "a unique" version: even in Polish there are more than one. Both Vatican *The New American Bible* https://www.vatican.va/archive/ENG0839/_INDEX.HTM and King's *James King James Bible Pure Cambridge Edition* were consulted. (29/12/2024) <https://archive.org/details/king-james-bible-pure-cambridge-edition-pdf>



Figure 1.1. An intellectual joke: how to design the world? The sequence that everyone proposes, regardless of language, age, education, is always the same: first the sun and the earth, as "common reason" suggests, and not hydrogen and stars, as physics says. SOURCE: Author

To understand what the beginning of the world was like according to modern science, we will first have to understand some principles of physics, chemistry, cosmology. But in order not to be "pundits", let us remember that questions about the universe are part of human culture in the broadest sense, from philosophy (metaphysics) to theology, from the visual arts to literature, up to astrophysics. The same question has been examined and interpreted in history in very different ways. Below are two images of God the Creator: a lesser-known, medieval one from the Norman cathedral of Monreale, another well-known, from the Renaissance, from the Sistine Chapel.



Figure 1.2. Two images of the creation of the world: on the fresco of the Cathedral in Monreale, a young, smiling God (and with a "technical" plan in his hand) is shaping the planets; according to Michelangelo, God resembles Zeus, complete with lightning gestures. SOURCE: Monreale Cathedral, Photo Ultreya, Milan; Sistine Chapel, Photo Vatican Museums, with kind permission.

1.5. An eternal universe?

The first question we face is what science says about the beginning and age of the universe. The problem is as old as human thought. Our ancestors looked up at the sky, admiring the immutability of the astral cycles, night after night, year after year the same repetition of the seasons. Thus, both the pyramids of the Egyptians and other megalithic constructions such as those of Stonehenge in England and Mnajdra in Malta, were based on solar cycles¹¹.

Today we know that the universe expands, and extrapolating this expansion backwards, we arrive at the age of 13.78 billion years. But there was a long way before this certainty. Already the two greatest Greek philosophers, Plato and Aristotle, discussed the question of the beginning of the universe. Plato had deduced the existence of a "maker of generation and of the universe".¹²

Let us say, then, why the Maker brought about generation and this universe. He was good, and in him who is good no envy is ever engendered about anything: being therefore exempt from it, he willed that everything should be generated, as far as possible, like him. If this reason were accepted by sensible men as the most well-founded reason of generation and of the cosmos, it would be accepted in the most correct way. For the god wished all things to be good, and none as far as possible evil, thus taking what was visible and not at rest, but moved disorderly and disorderly, from the state of disorder he restored it to order, having considered that order was absolutely better than disorder.

It was not lawful and it was not possible for the best being to do anything but that which is most beautiful: therefore reasoning he found that from things which are naturally visible it would not be possible to derive a whole that had no intelligence and that was more beautiful than a whole endowed with intelligence, and that moreover it was impossible for anything to have intelligence but to be separated from the soul. By virtue of this reasoning, by ordering together the intelligence in the soul and the soul in the body, he created the universe, so that the work he made was the most beautiful and the best by nature. So, then, according to a plausible reasoning, we must say that this world (*κόσμον*) is a living being endowed with a soul, with intelligence, and in truth generated thanks to the providence of God.¹³

¹¹ The megalithic stones of Stonehenge in England were placed so that on the day of the summer solstice the Sun rose between two "crosshair" stones. In the pyramid, the channel that started from the pharaoh's burial cell aimed, it seems, towards the North Star of the time. Today, due to the precession of the Earth's axis, that star is no longer polar.

¹² PLATONE, *Timeo*, trad. E. Pegone, Newton and Compton, Roma 1997, 29d.

¹³ Ibid., 29d-30c. [preliminary version, will be substituted with "official" translations]

Aristotle, habitually labelled as a "materialist" philosopher as opposed to "idealist" Plato, believed that the universe and time were eternal. This observation was derived from observations of the apparently eternal motion of the Sun and the planets¹⁴. Aristotle himself observed, however, that in "earthly" physics motion is not eternal: one body passes "motion" to another, the arrow flies because it is pushed by the air that closes behind it. But in the conclusion, there had to be a first *cause* of motion. In the *Metaphysics*, Aristotle also wrote about being "One", the prime mover.

The Principle and the first of beings is immovable and absolutely and relatively, and produces the first, eternal and one movement. And since it is necessary that what is moved should be moved by something, and that the Prime Mover should be essentially immobile, and that the eternal motion should be produced by an eternal being, and that the motion that is unique should be produced by a single being; and since, on the other hand, we see that besides the simple movement of the Whole, which we say is produced by the first and immovable substance, there are also other eternal movements of translation, namely, those of the planets (for the motion of the body which moves in a circle is eternal and continuous; and this has been shown in the books of *Physics*), it is necessary that each of these movements should also be produced by an immovable and eternal substance.¹⁵

Also in the *Physics* (VIII, 259a) Aristotle took up the arguments on the first cause of motion, which had to be one and eternal. Even if the Philosopher did not admit the beginning of time (and of the universe), his reasoning on motion, and on the existence of entities in general,

¹⁴ Aristotle, followed (obviously) that model that appears to the observer on Earth, that is, geocentric. But he was aware of the complicated movements of the planets that that model required. "However, it is necessary, if all the spheres together are to account for what appears to us, that for each of the planets there should be as many spheres minus one, which rotate backwards and always bring back to the same position the first sphere of the star which is from time to time located immediately below. Only in this way, in fact, is it possible for all together to produce the movement of the stars. Since, therefore, the spheres in which the stars move are eight for the first two, and twenty-five for the others, and, of these, only those in which the planet that is placed in the last place moves must not be made to go backwards, those that will have to produce the backward movement for the first two planets will be six. and for the next four planets, sixteen; the total number of spheres, those that move in the normal direction and those that turn backwards, will be fifty-five." ARISTOTELE, *Metaphysics*, 1074 a1-12, trans. by G. Reale, RCS Libri, Milan 2000, pp. 571-573.

¹⁵ Ibid., 1073 a27-34, p. 569. [see notes before]

led him to entirely *theological considerations*¹⁶: there must be a First, principal, supreme and eternal being. He wrote in the *Metaphysics*:

Therefore, this is a being that exists of necessity; and in so far as it exists of necessity, it exists as Good, and in this way it is Principle. (...) On such a Principle, therefore, the sky and nature depend. And his way of life is the most excellent: it is that way of life which is granted to us only for a short time. And in that state He is always. This is impossible for us, but it is not impossible for him, since the act of his life is pleasure. (...)

If, then, God is perpetually in this happy condition in which we sometimes find ourselves, he is perpetually wonderful; and if he is in a higher condition, he is still more wonderful. And in this condition He is actually found. And He is still life, because the activity of the intelligence is life, and He is precisely that activity. And his activity, which subsists in itself, is excellent and eternal life. We say, in fact, that God is living, eternal and excellent; so that to God belongs a life that is perpetually continuous and eternal: this, therefore, is God.¹⁷

But Aristotle realized that the passage of time gradually leads to the destruction of things. "There is no doubt that the passing of time is rather the cause of corruption than of formation (since change moves away from the initial state), and if it is the cause of creation or existence, it happens by pure chance."¹⁸ Aristotle, unlike all other thinkers until the middle of the twentieth century, also believed in the "internal life" of the stars. He wrote that there are "an innumerable number of stars";¹⁹ today we know that hundreds of billions of stars shine in our galaxy alone, visible on the night sky.

This, then, is the first aporia that one could rightly raise; the other concerns the cause that in the first sphere [i.e., the most distant] there is such a number of stars that the whole of their array seems to ascend to an innumerable figure, while the other stars [i.e., "wandering" stars, i.e., planets] are each placed separately in its own sphere, and two or more of them are not seen fixed in the same sphere.

¹⁶ The arguments on the first cause of motion and on the existence of a necessary entity were taken up a thousand years later by St. Thomas in his five ways to "prove" the existence of God.

¹⁷ ARISTOTLE, *Metafisica*, 1072 b14-30.

¹⁸ ARISTOTLE, *Fisica*, trans. Antonio Russo, Laterza, Roma-Bari (1991), IV 222b.

¹⁹ ARISTOTLE, *Del cielo*, trans. by Oddone Longo (Laterza, Bari, 1973), Mondadori, Milano 2008, p. 392. [provisional translation from Italian]

Of all this, in truth, it is well that we should try to realize as much as possible, although we have only scanty data from which to start, and this distance separates us from the phenomena related to them. However, if we investigate by means of arguments such as those which follow, we will see that there is nothing absurd in the aporia now proposed. But we imagine the stars as if they were bodies, or monads, having an order, but completely inanimate; instead, they must be conceived as participants in activity and life. In this way what happens in them will no longer seem absurd.²⁰

Considering ancient philosophers as obsolete can prove to be very risky. They still lacked scientific observations, but not the ability to reason...

The question of the eternity of the world and the corruption with the passage of time was taken up by Immanuel Kant (1746–1805). He realized that an eventual eternal world, that is, very, very old, would already be at a standstill. He wrote in *The Critique of Pure Reason*²¹:

For suppose that the world has no beginning in time; in that case, an eternity has elapsed up to any given instant, and therefore an infinite series of successive states of things has passed through the world. Moreover, the infinity of a series consists precisely in the fact that it can never be completed by means of a subsequent synthesis. Therefore, an infinite series of the world, which has already passed, is impossible, and therefore, a beginning of the world is a necessary condition of its existence.

Philosophy has not solved the question of the eternity of the world. But two centuries before Kant, another science was born, physics. Named as such by Aristotle, it was only with Copernicus (1473–1543), Galileo (1567–1642) and Newton (1643–1726) that it took on its modern appearance. Physicists often boast that they cultivate the matter that has defined the paradigms of modern science, which is based equally on experiment and theory. It is therefore appropriate to start from physics, astrophysics and cosmology in our journey through modern science, its discoveries, successes, but also the doubts that open up with all the subsequent partial answers, in their sequence.

²⁰ Ibid., 292a 10–22.

²¹ I. KANT, *Critique of Pure Reason*, Part II (Transcendental Logic); trans. by G. Colli, Einaudi, Turin 1957, p. 484, cited by P. DAVIES, *God and the New Physics*, Mondadori, Milan 2005, p. 37.

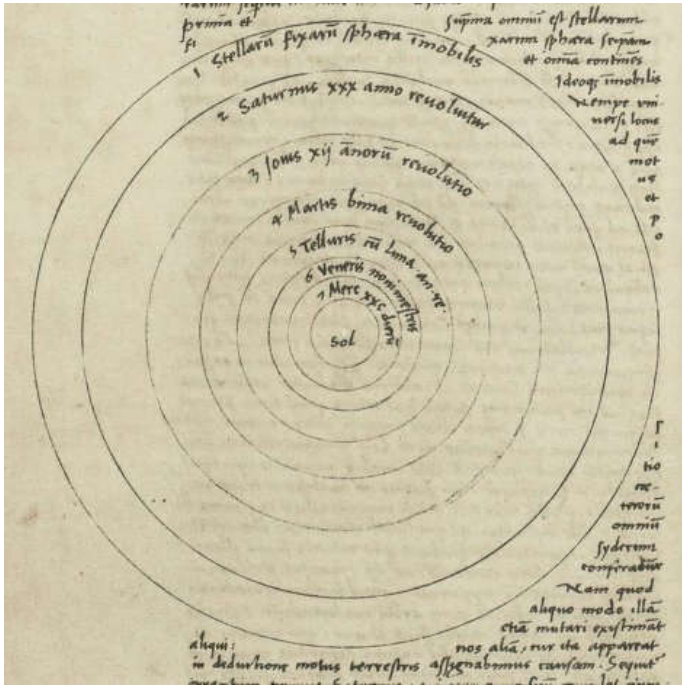


Figure 1.3. Nicolaus Copernicus expressed the cardinal points of his model already in the first pages of the treatise *De revolutionibus orbium coelestium* (1543). In Book I, chap. X, on the order of the celestial spheres this drawing appears: an elegant description is made corresponding to the physical reality of the Solar System and the fixed stars. Copernicus concludes this chapter with the words: "Certainly, this is the greatest divine work" (*Tanta nimirum est divina hæc Optima Maxima fabrica.*)

Physics and cosmology

2.1. The "principles" in physics

Physicists express themselves in a language of *principles*. Principles are the basis of our scientific *beliefs*: a set of experimental facts, proven and linked together through theories, which govern the universe (so, at least, we believe).

In mechanics, the science of motion and forces, three principles of conservation are listed: i) of momentum (i.e. velocity), ii) of energy (which can however be transformed into heat or other forms), iii) of angular momentum (which determines the "eternal" revolution of the planets).

In electromagnetism, we believe in the conservation of electric charge (i.e. the sum of positive and negative charges of the entire universe) and in the non-existence of magnetic charge (the so-called¹ magnetic monopoles): magnetic fields are created by currents, i.e. by flows of electric charges.

In the science of the heat, i.e. thermodynamics, the principle of equivalence of work and heat says that work can always be converted into heat (vice versa not always) and that heat is a form of energy *internal* of the body. Another principle of thermodynamics says that you cannot transfer heat from a colder body to a warmer body *without* work: the refrigerator requires a motor (or another way of providing work). In addition, you can always mix half a glass of hot water with half a glass of warm water, but separating them back from a glass of *warm* water is impossible.

¹ The non-existence of magnetic monopoles derives from Maxwell's laws: every magnet has both the "north" and the "south" poles. Scientists have produced many hypotheses about why monopoles don't exist and/or where to look for them and/or why they disappeared at the beginning of the universe, but none of these hypotheses is a theory proven with sufficient certainty.

In chemistry for centuries the principle of conservation of mass was valid (and it still applies): the sum of the masses of reacting substances remains equal to the sum of the masses of the products. This is Einstein's theory of relativity that introduced small, at first glance, corrections of this principle.

The principles complement each other. Although the principle of *energy conservation* says that the total amount of energy always remains the same², the second law of *thermodynamics* states that the universe is heading towards a "thermodynamic death": it will be neither hot nor cold, but *lukewarm*, and there will be no engines to move things.

The second principle of thermodynamics, which determines the operation of internal combustion engines (such as the internal combustion engine), states that the transformation of heat into mechanical energy always requires a (warmer) source of heat and a cooler radiator that absorbs the part of the heat that has not been converted into work. The amount of heat lost depends on the temperature difference between the source and the radiator.

The heat that flows from the source to the radiator leads to the equalization of their temperature. Then, in the long run, the transformation of heat into mechanical energy leads to the *thermal death* of the universe: the whole world will have the same temperature, that is, there will be no heat fluxes and consequently there will be no engines. It should be noted that the great engines on Earth, ocean currents and winds in the atmosphere, are always shaped by differences in temperatures.

2.2. The principles of conservation

It is therefore necessary to briefly review the fundamental "principles" of physics. These principles, in-between the discoveries of Galileo (1564-1642) and Einstein (1879-1956) made it possible to "remove" simple phenomena from philosophy (or magic), such as motion, heat, light, etc. But the interaction between physics ↔ and philosophy is mutually fertile: the principles of physics made it possible to discern

² With Einstein's theory of relativity, and the famous equivalence of energy E and mass m , $E = mc^2$ (with c for the speed of light), the principle of conservation of energy has been extended to the total conservation of energy and mass.

between many opposing reasonings, removing from many arguments the epithet of "speculations" that was assigned to philosophy.

2.2.1. "The principles" of Physics

Physics uses certain statements (based essentially on experiments) as *principles*. The first to be formulated, still in the Middle Ages, is the principle of conservation of motion, also called the principle of inertia. Bodies, once they have acquired velocity, retain it, except for the existence of frictional forces (such as air resistance). The *impetus* explains both the motion of a wagon pushed on a track and the eternal motion of the planets.

The second law of mechanics is the conservation of *energy*, the foundations of which were founded by Galileo: when a body is launched upwards, it loses speed (i.e. its kinetic energy) but acquires altitude (i.e. potential energy). When a body falls, its potential energy decreases but the kinetic energy increases. A pendulum at its highest altitude is stationary, at its lowest point it moves fastest. The sum of the two forms of energies remains constant (except for friction).

In the nineteenth century, after the construction of thermal engines (such as the steam engine), the conservation of energy was also extended to thermal phenomena: heat is also a form of energy and can be converted into mechanical energy. This is the first principle of *thermodynamics*.

But the second law of thermodynamics says that this transformation cannot reach 100% efficiency: part of the heat must always be lost in the radiator. So, the engine cools down and the radiator heats up: the temperature differences are reduced and in the long term the whole universe will have the same temperature. At this point it will not be possible to build heat engines: the universe is heading towards a thermal death.

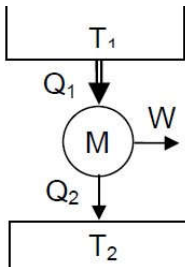


Figure 2.1. The operating principle of a thermal engine "M" (a steam turbine, an internal combustion engine, a typhoon in the atmosphere): the heat Q_1 flows from the hottest source (at temperature T_1) to the engine, which obtains the mechanical work (W). A part of the heat (Q_2) must flow to the tank at the coldest temperature (T_2). The maximum possible efficiency is equal to $\eta = (T_1 - T_2)/T_1$, where the temperatures are expressed in degrees kelvin ($K = ^\circ C + 273.15$). GK.

Immanuel Kant had created his philosophy before the formulation of the laws of thermodynamics (Carnot, 1824), using the same reasoning as Aristotle: time, by itself, leads to disorder: a kind of death. Physics had introduced a specific term to measure this disorder: it is called "entropy". Originally, entropy was defined as the ratio of the heat transferred to the temperature at which this transfer occurs. From the diagram in fig. 2.1 it can be understood that, in order to have a high efficiency of the heat engine, it is advisable to use very hot sources, so that the entropy is low.

With the birth of information technology, entropy was attributed the direct meaning of disorder: the greater the disorder, the higher the entropy. If two gases at different temperatures are mixed, their overall energy does not change, but entropy increases: it is no longer possible to separate hot molecules from cold molecules. As Aristotle wrote, time by its nature is destructive, because it consists of a certain number of changes, which remove what existed before (*Physics*, 221b).

To sum up, even before the twentieth century, there were strong indications that the universe had (once) begun, even if estimates made by physicists significantly underestimated its age. For example, Lord Kelvin (1824-1907), one of the founders of thermodynamics, estimated the age of the universe at around 50 million years, much less than the billion years estimated by geologists at the time on the basis of the stratifications of limestone visible in Dolomites (or Himalaya) and on the cliffs of the seas (Fig. 2.2).

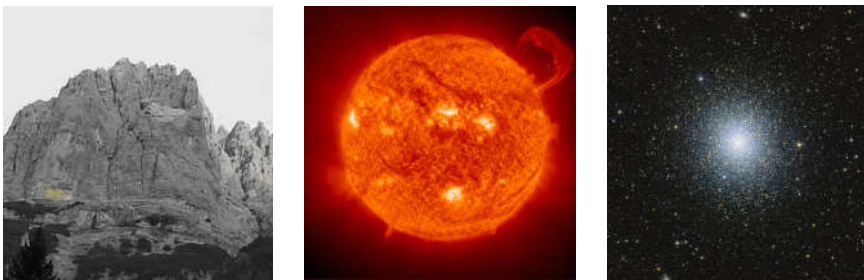


Figure 2.2. (a) The count of the layers, deposited year after year on the seabed and risen to form the Dolomites, testifies their age to hundreds of millions of years. (b) Still at the turn of the nineteenth and twentieth centuries, physicists were convinced that the Sun had existed for no more than 50 million years. Today, thanks to X-ray, ultraviolet photos, etc., we are aware of the violent thermodynamic fusion processes that take place inside the Sun and produce enormous amounts of energy. (c) Globular clusters are the oldest stars in the Universe. The Tucano cluster also contains neutron stars, which are 13 billion years old. MARIA KARWASZ; NASA; D. WOS.

Lord Kelvin based his estimates on the size of the Sun and estimated how many millions of years it would take a fireball to cool. He could not imagine an internal source of energy: hydrogen that burns into helium, losing the mass m but producing the energy E , according to the equivalence relationship between $E = mc^2$ (where c is the speed of light, 299 792 km/s).

Even the principles of thermodynamics must be re-analysed by the equivalence of mass and energy predicted by Einstein: the Sun produces enormous amounts of energy by converting hydrogen nuclei into helium. The amount is such that it has been heating the entire solar system for 4.5 billion years and will be enough for at least the next 10 billion years.

But, slowly, the hydrogen in the universe, the fuel of the stars, could run out: this will happen no earlier than 10^{13} years (i.e. ten billion, or a thousand times more than the age of the universe). A thousand times more, in 10^{16} years, the Earth (now completely cold) would be able to wander alone in the Universe. According to the estimates of the Swiss astro-physicist Arnold Benz³, the matter will still exist for the next 10^{35} (a billion of billion of billion of billion) years, if not beyond. Student usually add: “but we will not be present”. Who knows?



Fig. 2.3. The Earth will be able to host us for a few more billion years (barring unforeseen events). Then hydrogen, the primary source of solar energy, will begin to run out: this will cause the Sun to regrow, the Earth to warm and the oceans to evaporate. In the meantime, our Galaxy could collide with another, that of Andromeda. But a billion years is a long time... Illustration copyright © Ron Miller, with permission.

³ ARNOLD BENZ, *The Future of the Universe: Chance, Chaos, God?* (in German) Patmos Verlag, Düsseldorf 1997.

2.3. Two paradoxes of the sky

Another fundamental question concerns the existence of the boundaries of the universe. Copernicus (in 1543) wrote that the Earth, although large, is nothing compared to the universe, whose limits we do not know, which perhaps we cannot even know⁴. Since the time of the heliocentric theory, astronomers have abandoned the concept of celestial spheres⁵, the last of which contained fixed stars. The universe potentially became infinite.

A designer, in 1888 tried to deride the medieval images of a closed universe, see fig. 2.4. Paradoxically, a few years later, Albert Einstein proved that due to the limited speed of light, the universe we know is confined - by a radius of 13.8 billion light-years (about 1.3×10^{23} km). Beyond this sphere we cannot extend our knowledge.

Isaac Newton discovered the law of the universal gravity: all masses attract each other. This force does not allow planets to escape from the Sun and makes them to revolve on orbits around our star⁶. But a difficulty arises: since the force of gravity acts at infinite distances (even if it weakens with the square of the distance), in a fairly old universe all stars, interacting with each other, would have to come closer: the universe would collapse (or better - had already had collapsed) on itself. Neither the Universe exists any more, nor we.

Figure 2.4. In this image that appeared in 1888 in Flammarion's book in Paris, the author wanted to mock the medieval philosophy that placed limits on the universe. At the same time (1887) Abraham Michelson's experiment at Cleveland showed that we cannot determine the limits of the Universe. SOURCE: Wikipedia



⁴ «Nihil enim aliud habet illa demonstratio, quam indefinitam coeli ad terram magnitudinem. At quousque se extendat haec immensitas, minimè constat.» *De revolutionibus orbium coelestium*, L. I, cap. VI, "Cur ergo hacsitamus adhuc, mobilitatem illi formae suae a natura congruentem concedere magis quam quod totus labatur mundus, cujus finis ignoratur, sciri nequit, [...]" cap. VIII Wikisource p. 122.

⁵ The title of Copernicus' work "On the Revolution of the Celestial Spheres" seems to have been added by the Nuremberg publisher, a little frightened by the revolutionary scope of the book's theses. Copernicus examines the celestial bodies on their orbits, but not the "spheres".

⁶ We note that Copernicus used the same argument in response to objections that the Earth could disintegrate by turning (Book I, chap. VI).

The second difficulty concerns the starry sky, which remains black at night. An infinite universe should contain an infinite number of stars. Moreover, in the areas of the universe farthest from Earth there are an increasing number of stars⁷. Although their apparent brightness decreases with distance (similar to the force of gravity), the infinite number of stars should make the sky infinitely bright, both day and night.

Anticipating the discoveries of modern cosmology, both difficulties vanish if one assumes that the universe is expanding. Thus the stars "escape" each other's gravitational collapse. The radiation "delays" getting to us from the fleeing stars and the sky remains black at night. But experimental arguments to support the expanding universe thesis were lacking until the 1920s. A few years earlier, the technique for estimating the distance of galaxies was developed; and in 1915 Einstein formulated his theory of the equivalence between gravity and accelerated motion, called the general theory of relativity. The philosophical consequences of the results deduced from this theory surpass even the Copernican revolution.

2.4. Einstein and relativity

In 1905, Albert Einstein, who had just graduated from the Zurich Polytechnic (where he was denied the position of researcher), was working at the patent offices in Bern. A year earlier he married his beloved Mileva Milić and a son was born. 1905 was an *annus mirabilis* not only for Einstein but for all physics. In a paper discussing the properties of electromagnetic waves (i.e., light), Einstein concluded that it is not possible to detect whether an observer is moving in space or lying motionless: the measured speed of light does not depend on the motion of the observer relative to space.

His theory is called "relativity", although it should be called "objectivity". The core of this theory is that the laws of physics are the same for all observers moving at a constant speed (one with respect to the other). One could also say that this is not a new observation: it is difficult to recognize an absolute motion. Compared to what? The relativity of motions was already formalized in a mathematical way by Gali-

⁷ Assuming a constant density of stars in the universe, at increasing distances r the number of stars grows as the surface of the sphere, i.e. $4\pi r^2$.

leo; Copernicus had invoked it by explaining an apparent diurnal (and nocturnal) motion of the sky. Indeed, he quoted Virgilius⁸: the sailors on the ship that has set sail see the mountains moving away, and not the ship in motion.

But unlike common thought (and Galileo's mathematization), Einstein's relativity was a real revolution: the laws of physics (including the speed of light) are always the same, but the measure of space and time changes. With Einstein, space and time are not identical for the different observers but are relative: they depend on the reciprocal speed between the two observers.

Without going into a detailed mathematical formulation, by observing objects that move (relative to us), their size (in the direction of motion) shortens and time intervals lengthen. As in Figure 2.5. the airplane in motion (with a speed close to that of light) seems shorter. Where do these "deformations" come from?

Einstein derived in a purely theoretical way the narrowing of the coordinates of space and the lengthening of those of time, to "save" the equations of electromagnetic waves (more properly Maxwell's equations). A heuristic explanation of this phenomenon is presented in Fig. 2.6.

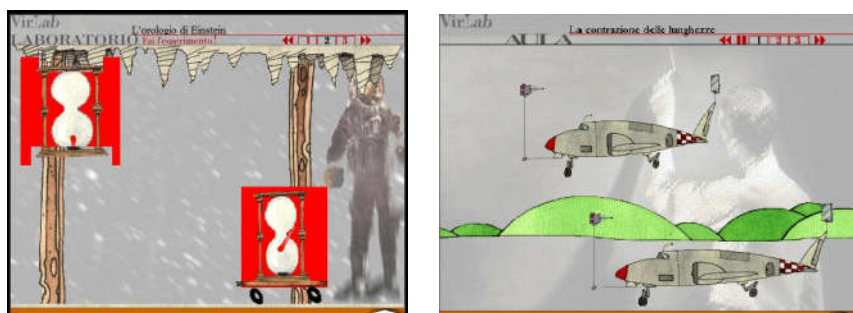


Figure 2.5. The principles of the special theory of relativity: bodies in motion seem shorter, time on clocks in motion seems to be late. SOURCE: UGO AMALDI, "Einstein and relativity", CD-Rom, Zanichelli, Padua 1999.

⁸ "We move away from the port, lands and cities by receding" (VIRGILIUS, *Aeneid*, L. III, 73, trans. Rosa Calzecchi Onesti, Edizioni Progetto Scuola, 1989).

The measure of space, greatly simplifying, lies in "throwing the eye",⁹ sending a ray of light towards the front of the approaching train and another (at the same time) towards the end of the train. But the beam sent towards the end takes longer to reach the target, and that in the meantime has already approached. Thus the measured distance is shorter. The key to this phenomenon lies in the constant speed of light; a ball sent towards the front window of the train would be reflected with a higher speed. For the light beam, the speed of arrival at the train and back is always the same: 300 thousand km/s.

The theory of relativity got its name from the fact that phenomena are *relative*: on two approaching trains, both observers are convinced that the *other's* meter is too short (and *that the other's* clock is behind¹⁰). So are the transformations discovered by Einstein an illusion? No! The real nature of relativistic transformations confirms the experiments. One of the most significant ones, on the lifetime of a subatomic particle, the muon, was made by an Italian scientist, Bruno Rossi¹¹, already in 1941.

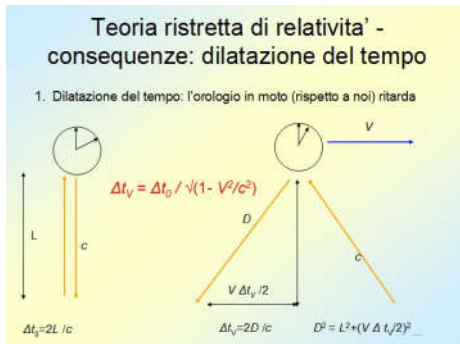


Figure 2.6. Time dilation in the restricted theory of relativity: reading the clock consists of sending a ray of light towards the clock on the wall, at a distance L from the observer. For a stationary clock, the light takes $2L/c$, but for a moving clock the distance that the beam makes is greater, due to the elongated path D . Thus, before the mobile clock reading returns, ours has already measured a longer time; the

other is behind. In other words, for moving objects, time passes more slowly. SOURCE: Own drawing.

⁹ "Buttare l'occhio" is not a very correct idiomatic expression in Italian, it would be better to say "to cast the gaze". In English we would say "drop an eye", in Polish we say "rzucić okiem" to describe a quick look.

¹⁰ Regarding this last statement, a question arises: which of the two twins ages less: who makes a space trip or who has stayed at home? In the restricted theory a paradox arises: both are convinced that the other ages less (both are in relative motion). The answer can only be given in the theory of general relativity: what left for space had to accelerate, so their situations are not mutually symmetrical (those who age longer depend on the biology of space flights).

¹¹ B. ROSSI, D. B. HALL, *Phys. Rev.* 59, 223 (1941).

Muons produced in the laboratory (in large particle accelerators, such as the one at CERN in Geneva) live just 2.2 microseconds. Many muons are produced by cosmic radiation (i.e. very fast protons from the Sun) in the upper atmosphere. Assuming that muons produced at an altitude of 10 km travel at the speed of light, they would need 30 microseconds to reach the surface of the Earth: according to "normal" arithmetic, so they cannot be detected at sea level, unless Einstein's arithmetic is used. With the speed of $0.98c$, the lifetime of a muon becomes 50 times longer: the muon can reach the ground.

The most important consequence of Einstein's special relativity for our worldview is the insurmountable limit of the speed of light: no information can be exchanged at a faster speed¹². Thus, the universe could extend to much greater distances than those observed by us from 13.8 billion light-years, but we have no way of discovering it. As Copernicus already wrote, "the universe is large: we do not know its limits, nor *can we* know them".

2.5. The elevator in free fall

A very simple question (can we determine a motion with a constant velocity?) led to revolutionary consequences. Einstein later asked another similar question: can motion with a constant *acceleration* be detected? For example, how do we know that the lift in which we are enclosed starts moving upwards or downwards? Do we feel it?

Yes, we feel it, because if the elevator starts upwards, for a moment our weight seems greater; if the elevator starts downwards, for a moment we feel gravity partially absent. Note! There is no way to distinguish the fictitious forces during the acceleration of the elevator from the force of gravity: both act in the same direction. Almost... There is a subtle difference between an accelerating elevator and the Earth's gravitational field. On Earth, all objects seem to fall vertically, while in reality they fall towards the centre of the Earth (as already Aristotle said), that is, in a *radial* direction. Given the enormous size of the Earth, the motion downward (of the elevator) and the radial trajecto-

¹² It must be remembered that the speed of light in material media, such as water, air, even interstellar space, is less than c ; so even the gravitational wave (detected on 17/08/2017) seemed faster than light: no! The speed of the gamma radiation detected was *less* (for a part of 1020) than c . In certain situations, electromagnetic waves also have a speed (so-called *phase*) greater than c , but they cannot carry information.

ries look identical. But this is not the case: the gravitational field *curves* parallel trajectories, see Fig. 2.7.

In other words, there should be a relationship between the gravity field and the *curvature* of the space (more precisely: of the space-time). Einstein meditated for almost ten years on an adequate formulation of the generalized theory of relativity: he had to develop (with his colleague Grossmann) a new branch of mathematics. Finally, between 1914 and 1917 Einstein formulated step by step (but the first steps were wrong) his general theory. The theory links the geometry of space (previously always considered simple, 3D, as formulated by the Greek mathematicians Pythagoras and Euclidean) and the gravity.

The equation, in mathematical details very complicated, in the concise form surprises with its beauty and visual sobriety

$$\mathbf{G} = (8\pi G/c^4) \mathbf{T}$$

where a complex mathematical object (the tensor) $\mathbf{G}$ describes the curvature of the space-time due to the action of gravity and the tensor $\mathbf{T}$ describes the energy (which is equivalent to the mass). For the rest, these are universal constants: the speed of light c , the gravitational constant G and the geometrical number π .

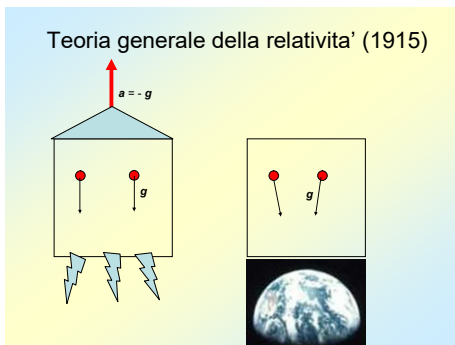


Figure 2.7. A summary of Einstein's idea of general relativity: how can you distinguish an accelerating rocket from the presence of a body (e.g. the Earth) that exerts a force of gravity? In the rocket all objects fall along parallel lines; on the surface of the Earth the trajectories are directed towards the centre of the Earth and are not perfectly parallel. This leads to the concept of the *curvature* of the space-time, in the presence of gravitational masses. But,

given the equivalence of mass and energy, Einstein's equation compares the curvature tensor of space with the mass-energy tensor. SOURCE: GK

Immediately after the formulation of general relativity, the problem of the collapse of the universe arose again. At that time, the first mathematical solution of Einstein's equation obtained by Willem de Sitter (in 1917) described a stationary universe, but with a zero density of matter: an infinite, stable, but perfectly empty universe! Einstein

himself, seeing the difficulty, introduced an *ad hoc* term into the equation: a type of artificial pressure to prevent the collapse of the universe. This term Λ was called "cosmological". Thus the equation takes the form

$$\mathbf{R}_{\mu\nu} - \frac{1}{2} \mathbf{g}_{\mu\nu} \mathbf{R} + \mathbf{g}_{\mu\nu} \Lambda = \frac{8\pi G}{c^4} \mathbf{T}_{\mu\nu}$$

where it is made explicit with indices that the energy $\mathbf{T}$, the curvature $\mathbf{R}$ and the metric $\mathbf{g}$ of the space-time are so-called tensors.

Einstein always considered this term "the biggest mistake of his life". Anticipating again the conclusions of XXIst century astrophysics which measured this pressure, it seems that the term "cosmological" was Einstein's greatest intuition: the Universe had its beginning!

But returning to the chronology of events, the solution of Einstein's equation that predicted a "long-lived" universe was published in 1925 by a Russian mathematician, Alexander Friedmann (1888-1925), who proved that the universe must expand in order to (ever) exist.



Figure 2.8. When Georges Lemaître lectured at Princeton in 1933, Albert Einstein exclaimed: "This is the most beautiful and comprehensive explanation of creation that I have ever heard."¹³ The idea of the 'beginning in time' was also appreciated by Pius XII in 1951. SOURCE: Catholic Education Resource Centre.

A Belgian priest, Georges Lemaître (1894-1966), a canon at the cathedral of Malinas, obtained an independent solution in 1927, but with the same conclusions¹⁴. He hypothesized the beginning of the universe as "a single primordial atom" which later split into several atoms: "Then the beginning of time took place a little before the first atom

¹³ «This is the most beautiful and satisfactory explanation of creation to which I have ever listened». H. KRAGH, *Cosmology and Controversy*", Princeton 1996, p. 55, citato da https://en.wikipedia.org/wiki/Georges_Lemaître.

¹⁴ The author of another cosmological revolution, Nicolaus Copernicus, was also a priest: canon of the cathedral of Frauenburg (Frombork) in Poland.

split in two."¹⁵ Einstein commented: "This is the most beautiful description of Creation that I have ever heard." Not the beginning of the world, but the "Creation", said Einstein, see fig. 2.8.

The consequences of the equation of general relativity are much broader than the bulge of the Universe: they affect our conception of space and time. But first let's go back to astronomical observations.

2.6. Planck: What colour is the Sun?

What colour is our star? The answer seems obvious: a yellow fireball. At least it seems so. But already in the rainbow, the sunlight "reflected" in the rain droplets shows many colours, ranging from red to violet. Yes, sunlight contains all these colours. The strongest are yellow and green, while those on the edges of the rainbow are less intense.

The sensitivity of the human eye to different colours varies a little, but physicists have measured the intensity of colours in the *solar spectrum*, obtaining a graph as in Fig. 2.9. The spectrum recorded by the physical instruments extends above the red colour and a little below the purple colour. We are talking about *infrared* and *ultraviolet light* (in the rainbow infrared light is above and ultraviolet light is below: it was Newton who held the glass prism upside down).

The Sun is a ball of very hot (and dense) gas that reaches 15 million centigrade at its centre. But towards the surface the temperature of this gas decreases and amounts to only 5500°C (about 5800 K). What remains a bit surprising is that despite being a ball of gas, the distribution of colours (the "spectrum" as in Fig. 2.9b) resembles the light emitted by a horseshoe heated in a blacksmith's oven. The mathematical shape of the two spectra is also similar: it depends on the temperature and can be described with the same formula called "blackbody". In fact, both the horseshoe and the filament of an incandescent bulb are black when cold. As the temperature increases, the colour changes from black cherry to red, orange, yellow, Fig. 2.10a.

The mathematical relationship between the spectrum and the temperature of the black body, known "by eye" from the Iron Age, was explained only in 1900 (exactly on Thursday 14 December), by a physics professor from Berlin, Max Planck. To do this, he had to assume that the energy of light is emitted in portions, in "quanta". That

¹⁵ *Interdisciplinary Documentation of Science and Faith*, <http://disf.org/lemaitre>.

day quantum physics was born, which today is the basis not only of physics, but also of chemistry, molecular biology, astronomy.

Using the mathematical description of the spectrum of an incandescent body, we can determine its temperature without touching it. Thus, in the astronomical field we can estimate the temperature of the most remote stars, as in Fig. 2.10b.; We can also measure the temperature of outer space (which is not zero Kelvin). With other methods, always analysing the details of the "colour", i.e. the *spectrum*, we can guess the chemical composition of remote stars. The study of spectra is a method of examining objects (atoms, stars, the entire cosmos) without touching them.

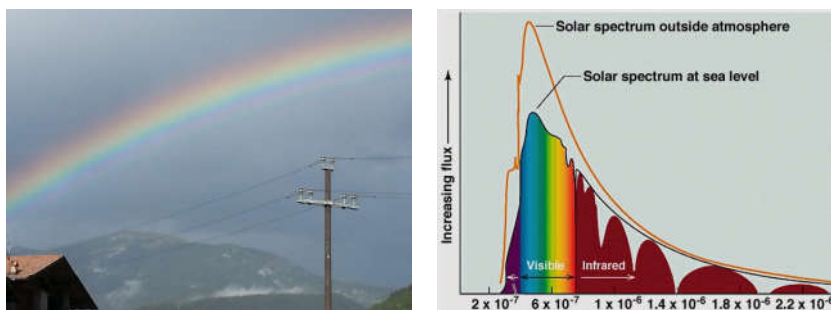


Figure 2.9. (a) The rainbow in Trentino; the rainbow appears when the sunlight behind us is reflected (and refracted) in the droplets of rain in front. Below the band of seven colours you can also see fuchsia and magenta, which derive from another optical phenomenon: interference. The decomposition of white light into different colours is an example of a "spectrum." (b) Visible light (the rainbow) occupies only a part of the Sun's *spectrum*, but contains 50% of the energy. The atmosphere attenuates sunlight a little, eliminating the more energetic ultraviolet light; moreover, the atmosphere is not transparent to the infrared, which is absorbed by both H₂O and CO₂. SOURCE: <https://ivanpankov.files.wordpress.com/2009/07/sun-spectrum.gif>.

Our knowledge of the most remote universe begins with the work of a Jesuit, Father Angelo Secchi (1818-1878), director of the Astronomical Observatory of the Roman College. He was the first to study in detail the different colours of the stars – red, yellow, white-blue. But in addition to seeing the "colour," Secchi studied the details of the spectrum: lines that appear in the continuous background. Just as Galileo was the first to point the telescope at the sky, so Secchi pointed the *spectrometer*. This made it possible not only to determine the "colour" of the stars and their temperature, but also their size, distance, age, composition, etc. But our understanding of stars grew slowly.

2.7. Aristotle: The life of stars

Aristotle was the first to hypothesize the evolution of stars. But it was more than two thousand years before astronomers took his words seriously. Before, many "painstaking" observations were needed, not only by Secchi but by numerous astronomers (or: women-astronomers).

In the mid-nineteenth century, a new method of studying matter in the gaseous state was introduced: the colours of the light emitted during electric discharge. Each substance, heated, or rather evaporated in the flame, emits a characteristic colour: sodium (i.e. the table salt) – yellow, copper salts – green, rubidium salts – ruby colour. This is also a way to get the different colours in fireworks.

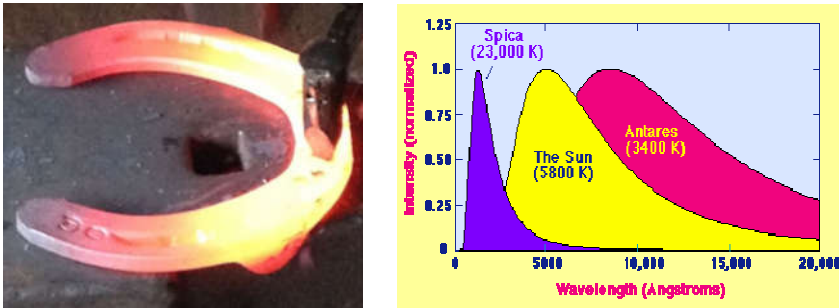


Figure 2.10. (a) The colour of the horse-shoe (and the filament of a light bulb) changes with temperature: from red (at 1000°C) to yellow to glowing white at 3000°C . (b) The colour of the stars also changes in the same way: the Spica, with the surface at 23000°C looks blue compared to the Sun (5500°C) and the large but relatively cold Antares (in the Orion belt), which is red. SOURCE: NURE AGLIO; ERIC C. BLACKMAN.

The same principle is exploited in luminescent lamps: yellow in the street contain sodium vapour, white in offices contain mercury, red in advertising signs contain neon. In astronomy, this technique, called *spectroscopy*, allows the identification of chemical elements in the stars. Thus, helium was discovered, which is the main gas in stars besides hydrogen. In this way we know that even iron vapours are found on the surface of the Sun.

The characteristic colours of the chemical elements found in stars appear in the spectra as narrow lines on a continuous background. It took a lot of patience to fix these lines on photographic plates (today it can be done with a mobile phone).

The studies of the colours of the stars, begun by Father Angeli Secchi, were resumed at the beginning of the twentieth century at Harvard (today the telescope used is located in Toruń), photo 2.12b. A group of scientists¹⁶, night after night, photographed the spectra of almost a million stars.

Initially, the characteristics of these spectra were unclear. So the stars were classified as A, B, C, then M and O again. Essentially, the white stars were called "A", yellow "G", red "M". Then *spectral similarities were discovered* that allowed stars to be classified according to their temperature and brightness in the so-called Hertzsprung-Russell diagram.



Fig. 2.11. The colour of the star indicates its temperament. From here you can deduce its size and age. Here we show a group of stars near Antares in the constellation of Scorpion. Antares is red in colour, but seen through interstellar clouds it looks yellow-green.

SOURCE: DOMINIK WOS

<https://astrofotografia.eu>

It was soon understood that differences in colour, brightness and size are evidence of well-defined life cycles of stars. As Aristotle has already quoted: "to us the stars seem immutable but in reality they function and rejoice¹⁷ in life". Several branches of the R-H diagram show the path of evolution of stars: the separate branches, such as "white dwarfs", are the final stages, a "parking lot", before going out

¹⁶ We remember some names: Annie Jump Cannon, Williamina Fleming, Henrietta Swan Leavitt, Antonia Maury.

¹⁷ The Italian translation of the sixteenth century says: "But of them, as of bodies, & united, having order and inanimate to all we think. And it is necessary to esteem, as if you have life, & act." *De celo et mondo Aristotle translated from Greek into the vernacular Italian*. For Antonio Brucioli. Printed in Venetia, for Bartholomew Emperor in 1552. Google books: iiVRxG4Lf7UC, p. 133. A Polish translation says: "and they rejoice in life" (trans. P. Siwek, PWN, Warszawa, 1990).

forever. Instead, the higher the temperature of the star and its mass, the shorter its life. For example, the blue giants will explode fast, in a hundred million years. The Sun is neither particularly large nor hot; for this reason its evolution has lasted for several billion years, allowing life on Earth.

The life cycle of stars gives the first experimental indication that the universe is not eternal: the theses of the University of Paris on the eternity of the world were wrong, if not downright heretical!

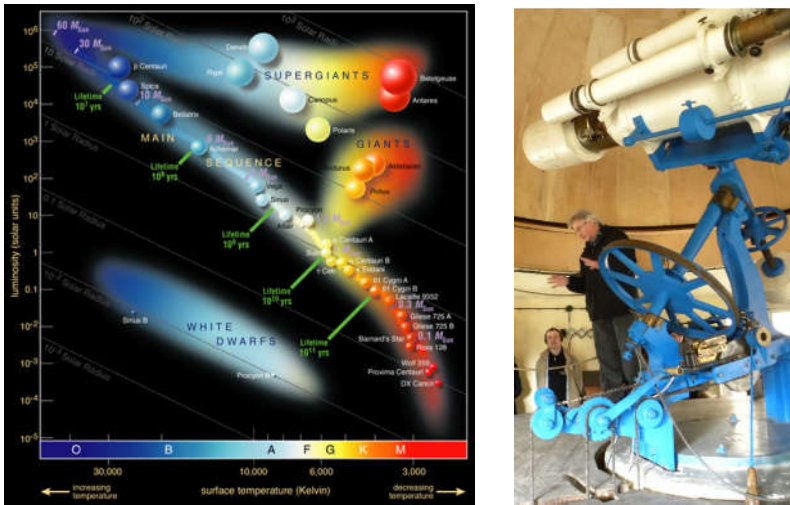


Figure 2.12. (a) The Hertzsprung-Russell diagram: the ratio between the absolute luminosity and the temperature of the surface, with some characteristic stars of our Galaxy marked. (b) The historic Harvard telescope that allowed this classification is now located in Toruń, at the University observatory, in exchange for one hundred years. SOURCE: ESO; photo MARIA KARWASZ.

2.8. The escape of galaxies

The study of the life paths of stars has also allowed a step forward in cosmology, that is, in the study of the entire universe. Among the stars classified at Harvard there is a type of variable star, δ -Cephei, of the constellation of Cepheus, identified as such as early as the eighteenth century. The peculiarity of variable stars called *Cepheids* is that their brightness gradually decreases within a couple of days, and then recovers rapidly. These are probably red giants that towards the end of

their life cycle temporarily collapse, only to ignite again¹⁸. By measuring their apparent brightness and, with a stratagem described below, also their distance, it was concluded that the period of variability of Cepheids depends on their size. Thus, astronomers gained a powerful tool, a way of measuring the absolute distances of the stars, even if only of Cepheids.

A few Cepheids were discovered in a galaxy closest to ours, the Large Magellanic Cloud, again by scientific astronomers at Harvard. Then, in the twenties of the twentieth century, by Edwin Hubble, in the Galaxy of Andromeda, 2 million light years from us and then in the galaxies even more distant.

Hubble's great discovery, however, was another: he realized that the *spectral* lines of the stars in distant galaxies are shifted with respect to the lines of the stars in our Galaxy. This shift always takes place in the same direction: towards the red. The same effect happens when an ambulance moves away from us: the siren sounds lower than when it approaches. The phenomenon (for the acoustic siren) was discovered in 1842 by an Austrian physicist, Christian Doppler. Today the Doppler's effect is used both to assess the escape velocity of distant galaxies and for the velocity of the human blood in the veins.

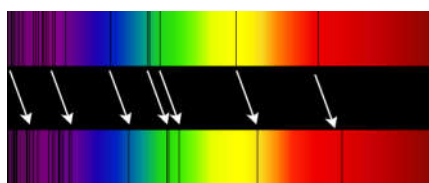


Figure 2.13. The Doppler effect allows us to evaluate the escape velocity of distant galaxies: the spectral lines of the Sun, upper panel (absorption spectra – the red and blue lines are due to the presence of hydrogen) *all* move red-ward in the light

of a distant galaxy (BAS11, lower panel). The displacement depends on the escape velocity and increases with the distance from us: the entire Universe swells like a leavening panettone. SOURCE: H.T. STOKES, BYU.

Combining the knowledge of the absolute luminosity (i.e. at a standard distance) of Cepheids with their escape velocity, led to the conclusion not only that the Universe is expanding, but also that the escape velocity of galaxies increases with their distance from us. Moreover, it was clear that it is not possible to determine a central point of this inflation. The Universe swells, but like leavening bread: uniformly, in all directions.

¹⁸ Another type of variable star is the Betelgeuse, Orion's alpha, a red giant ready to explode. This explosion may come within the next 500 years.

From the relationship of the speed on the distances between galaxies, the first estimate of the size of the Cosmos could be derived. Then, through Einstein's principle, the rough estimate of the age of the Universe was obtained: about ten billion years. Much more than the estimates of physicists (Lord Kelvin) and even geologists.

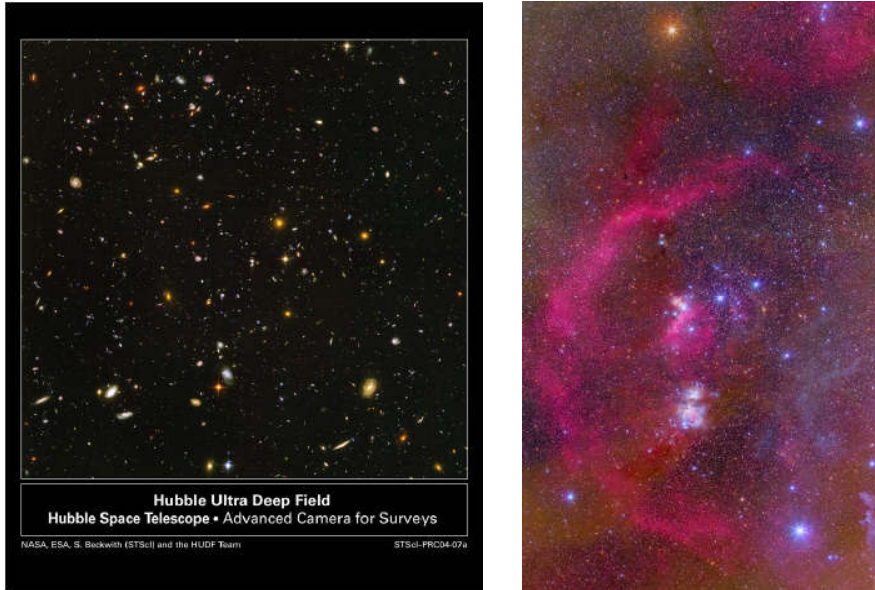


Figure 2.14. (a) In 2003, the Hubble Space Telescope was pointing for a couple of months at a region of the sky where there were no bright stars. This made it possible to observe very faint objects: distant galaxies. In this photo you can see that some small objects have a much redder colour than others: the apparently red galaxies are similar to the blue ones, but far away. It is the confirmation of the original Hubble observation: the Universe is expanding and the escape velocity increases with the distance. (b) The constellation of Orion, beautiful, clearly visible in the evening hours of winter above the southern horizon. Above, Betelgeuse, Orion's alpha star, a red giant ready to explode. SOURCE: Hubble Telescope; DOMINIK WOS.

2.9. The supernovae

Measurements of the brightness of variable stars of a well-defined type, Cepheids, have made it possible to verify that galaxies are moving away from Earth. The decisive characteristic of Cepheids for this verification is the precise dependence of their brightness (which depends on their volume) on the period of variation (which corresponds

to the period of swelling). Cepheids are, on average, from one thousand to ten thousand times brighter than the Sun, but this brightness is not enough to measure the distances of galaxies not a few million but a few billion light years away¹⁹: another methodology had to be found. And an example was ready from half a millennium.

In 1572 a "new" star was observed in the constellation of Cassiopeia, very bright - as bright in the first months as Venus. It was an explosion of a star that lies quite close to us, about 9 thousand light years from Earth. Today, the remnants of this explosion are barely visible in the night sky today, Fig. 2.16a. A similar event was observed in 1604 by Johannes Kepler (the first to note it was an Italian astronomer Lodovico delle Colombe). The explosion happened 13 thousand light-years from Earth and the initial brightness of the "new" star was a little less than that in 1572.



Figure 2.16. (a) The remnants of the supernova AD 1572 (by Tycho Brahe) seen in X-rays: in red the low-energy rays, in blue the high-energy rays. (b) The remains of a supernova (G299) that must have been visible to the naked eye 4500 years ago. SOURCE: chandra.harvard.edu.

In the Chinese chronicles in the year that corresponds to our 1054 DC, a supernova was described in the constellation of Cancer. The same star was noticed by the Indians in New Mexico. From the estimates made by astronomers today we know that that supernova was visible even during the day. In fact, the explosion took place "only" at a distance of 6.5 thousand light years from Earth.

¹⁹ Remember that the observed brightness changes like the square of the distance, so a factor of ten in terms of the distance makes a difference of a factor of hundred in terms of the observed brightness.

It can be seen that the apparent brightness, i.e. seen from Earth, decreases with the square of the distance from the supernova. In other words, the absolute luminosity (i.e., measured at a standard distance) for all supernovae remains the same.

As in the case of Cepheids, supernova explosions are also caused by well-defined processes and mark the depletion of a certain type of nuclear fuel that powers the "star oven". That is! many supernovae have similar dimensions and temperature at the time of the explosion: we found another standard candle.

In the last thousand years of written history, probably 5 supernovae have been noted, which correspond to the explosions of stars in our galaxy, i.e. about one every two hundred years. Then, the supernova shines for a couple of months and fades in the space. But the Universe is full of galaxies. With increasingly powerful telescopes, astronomers have spotted several supernovae in very distant galaxies. To sum up, with the redshift in the colour of galaxies we can measure their "escape" velocity, even if it would be more correct to speak about the inflation rate of the entire Universe. By measuring the apparent brightness of supernovae in distant galaxies, we can determine their distances with a fair amount of precision.

In 2011, the Nobel Prize in Physics was awarded to three astronomers for precise measurements of the expansion rate of the universe, using a certain type of supernovae observed at great distances (billions of light-years from Earth). The aim was to establish whether the rate of expansion was slowing down after the Big Bang and how. It would be natural for this speed to decrease with the passage of time (as we also see in "planetary" nebulae after the explosion of the star, see fig. 2.16). Then, in a few billion years, this speed could be reduced to zero, and the universe would have to collapse in on itself.

The answer obtained after several years of observations was surprising: the Universe is inflating not by inertia but due to an "internal pressure". In other words, the measurements confirm the existence of the *cosmological* factor in Einstein's equation of general relativity, also giving a precise value. But in addition to this, it was discovered that this speed of expansion has not been constant in the history of the Universe: after a rapid initial inflation, the expansion has slowed down, to accelerate in the last billion years. In the words of Saul Perlmutter, one of the winners of the Prize, this was the real surprise:

Visibly, we have a Universe that is dominated by some new ingredient, a previously unknown 'dark energy', which causes the Universe to expand faster and faster. It is so rare that we encounter something that is not part of our current physical model! This is one of the best results that can be achieved in a project like this. I feel very lucky to have been able to work on this project, because any of its results would have been exciting: we could have discovered that the Universe was infinite or that it was finite and heading towards an end. Both of these results would have been great. Instead, we found an answer that was even better than "great", and that was the surprise. It's something you could never dream of in science.

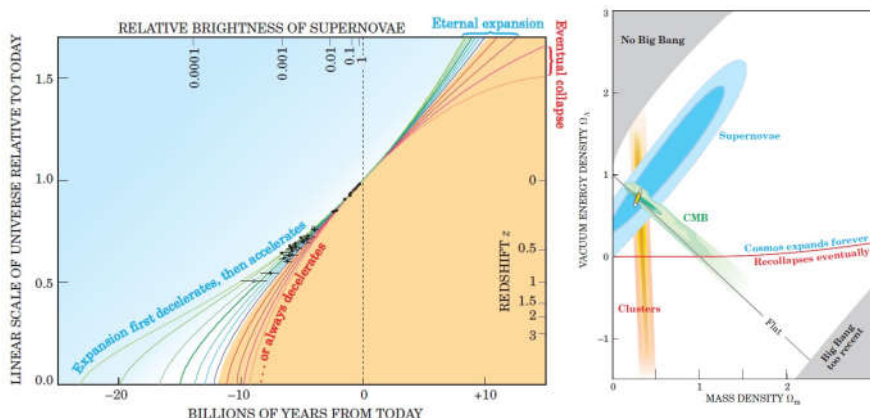


Figure 2.17. Two drawings from the paper by Nobel Prize winner Saul Perlmutter: (a) the decisive measurement of Type Ia supernovae at great distances (billions of years) from Earth; the graph presents the history of the Universe up to 10 billion years ago: the brownish area corresponds to the decelerating Universe, the blue area to the accelerating Universe. The measured points are located on a curve of the universe that after the initial explosion decelerated its expansion, to accelerate a few billion years ago. Now everything points to an infinite universe, expanding faster and faster. b) Other (theoretical) possibilities for the universe: no Big Bang (upper left corner), a too recent Big Bang (lower right corner); The red curve separates the universe that expands forever (above) from the universe that shrinks. The black line indicates the "flat" universe, i.e. 3D. Several measures are congruent with each other. SOURCE: Physics Today 56, 4, 53 (2003) © American Institute of Physics.

And so Saul Perlmutter continues his reflection, which is not only methodological, but also philosophical:

This result is a perfect example of how science can often be double-edged. On one hand, it was possible to discover something that was a real surprise for all of us because our field, physics, had already made very great progress in understanding the Universe. Less than a century ago, we had no idea that there is anything more to the Universe than our own Milky Way. The im-

mense size of the Universe, the fact that it is expanding, the fact that it is populated by objects such as exploding stars: all of this and more had to be discovered before we could do the work that led us to contemplate an unknown form of energy that contributes to more than two-thirds of everything that exists.

It is extraordinary how much we have understood, but on the other hand it is extraordinary how much is the mystery that has opened up as the result, and how much we still have to discover. One of the real pleasures of doing science – which will continue to be true, I believe, any day in the coming centuries – is that we have so much knowledge built up, but there is still so much for us to discover.²⁰

We know ourselves that there are new many worlds to see, but hearing the same opinion from the Nobel Prize winner, discoverer of the mysterious forces that pervade the entire Universe, is something else entirely...

2.10. The Finger of God

Measurements of supernova stars in distant galaxies not only confirmed Einstein's intuition, proving the existence of a "dark" energy, but also showed that the rate of expansion is variable. On the pages of the English Wikipedia, on the occasion of the awarding of the Nobel Prize in 2011, a very original cartoon appeared (see fig. 2.18.). The title of the page, "Fingers of God", was soon changed and currently reads "Red-shift space distortion".²¹

This "finger of God" appeared on Wikipedia also because we know that galaxies form larger groups (the "clusters"), composed of a few dozen of them, then the clusters form the super-clusters, over distances of 500 million light years. Finally, the super-clusters are gravitationally linked to form a gigantic web that fills the Universe (see fig. 2.18b.). We have no plausible explanation for the reason for this web.

Is there anything greater than the entire Universe? Many scientists and many pseudoscientists make various speculations. Our Universe that was born by "sucking" energy from another, parallel universes like separated soap bubbles, universes closed on themselves like a tangle of mutually connected key rings, etc. To all these ideas, which

²⁰ S. PERLMUTTER, *Measuring the Acceleration of the Cosmic Expansion Using Supernovae*, Nobel Lecture, Dec. 8th, 2011, p. 25. (C) Nobel Foundation. <https://journals.aps.org/rmp/pdf/10.1103/RevModPhys.84.1127>.

²¹ https://en.wikipedia.org/wiki/Redshift-space_distortions.

cannot be verified, then, according to "Ockham's razor" that do not exist, it is convenient to oppose St. Augustine:

God created the world...

4. 1. The world is the greatest of visible beings, God the greatest of invisible beings. We perceive the existence of the world, we believe the existence of God. And we believe that God created the world because no one can give the certainty that God himself gives of it. Where did we hear his voice? Nowhere is it so well as in the holy Scriptures, in which one of his Prophets said: *In the beginning God created heaven and earth*. This Prophet was not present when God created heaven and earth, but there was the wisdom of God, by which all things were made.²²

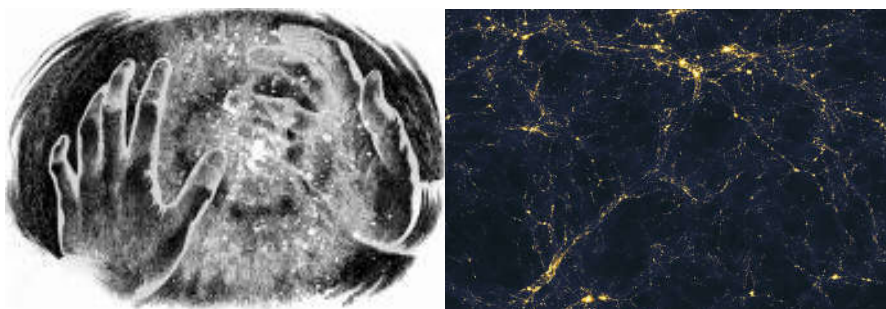


Figure 2.18. "The finger of God" (Fingers_of_God) the English page of Wikipedia (in 2011, now changed. (b) Filaments of Galaxies seen at the scale of the entire Universe: we don't know why galaxies form the largest groups, called "clusters" (we speak of a mysterious dark matter as a ligand), then we don't know why the cluster form filaments like a spider's web, we don't know if the universe extends beyond the visible limits: there are still more questions than answers.

FONTE: Wikipedia, 2011; Wikipedia 2019.

The lack of answers from astrophysics brings us back to metaphysics. Modern cosmology has set limits on our cognitive possibilities. The first was Copernicus, then Newton, Einstein and Perlmutter.

2.11. Our cosmological limits

What are the philosophical consequences of modern cosmology? Before, after the brief illusion of the Enlightenment, we again know our limits. Newton's second law says that to reach a certain speed it is

²² AURELIO AGOSTINO, *Città di Dio*, L. XI, p. 177, Acrobat Edition edited by Patrizio Samami: <https://giuseppicapograssi.files.wordpress.com/2013/01/ebook-ita-filosofia-s-agostino-la-città-di-dio.pdf>.

necessary to act with a certain force for an appropriately long time. This also means that energy is needed to accelerate. Newton's law is the first of our limits in space-time travel: getting to the edge of the universe is impossible.

The "corollary" of Newton's second law is Einstein's theory of relation: two speeds of light cannot be added together to obtain a double speed. In any case, the speed of light remains maximum for any transmission of material objects.

Usually, Newton's second law is written in the form

$$\mathbf{F} = m\mathbf{a}$$

where $\mathbf{F}$ is for acting force, m for the mass that is accelerated and $\mathbf{a}$ for acceleration (in bold it is marked that $\mathbf{F}$ and $\mathbf{a}$ are vectors, i.e. they are characterized not only by their values, but also by their direction).

But acceleration is the growth Δv of velocity in the time interval Δt : $\mathbf{a} = \Delta v / \Delta t$. Thus Newton's equation can be described as

$$\mathbf{F} \Delta t = m \Delta v$$

from where it is clear that to increase speed more you need either a greater force or a longer time. Thus Newton's second law (together with the limited resources of energy to derive infinite forces) becomes our first "anchor" against infinitely distant travel in a limited time. Our minds can reach the edge of the universe in a second, our bodies would have taken billions of years.

Thus, the finite speed of light also places spatial limits on the boundaries of our knowledge: we do not know if the Universe extends beyond the distance of 13.78 billion light-years, because light from beyond this distance has not yet reached us.

In addition, Newton's second law also changes: the mass m to be accelerated is no longer constant, but increases infinitely, as its velocity v approaches the speed of light c , according to the formula given by Einstein

$$m = m_0 / \sqrt{1 - v^2/c^2}$$

where m_0 is defined as the "mass at rest", i.e. without movement.

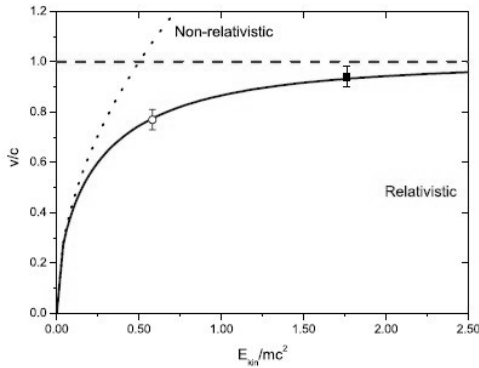


Figure 2.19. It is impossible for an electron (and any other object with mass, i.e. all objects except photons and gravitons) to move at the speed of light: the mass of the electron m with respect to its "rest" mass m_0 grows vertically towards the limit of the velocity v equal to the speed of light (two experimental points are shown). SOURCE: M. LUND. U.J. UGGERHØJ, Am. J. Phys. 77 (1982), p. 757.

Thus, the infinitely far-away is unattainable for us: accelerating to the speed of light is practically impossible.

2.11.1. *The Terror of a black hole*

At the end of interactive astronomy lessons for children, enriched with experiments, many questions are usually asked. Regularly half of them concern black holes. Do they exist? Can you enter them? Can you get out of them? What is the world like inside?

The concept of a black hole is easy to explain. Very massive stars, above about ten times the mass of the Sun, can end their lives as a black hole: it is an object so heavy that nothing, not even light, escapes their gravity. As we have already seen, stars, when they run out of fuel, can explode as supernovae, but they can also collapse on themselves and form balls of very dense mass. The density of these stars is so great that a pin-head made of this kind of matter would weight as much as a 10-story building. The density of mass inside a black hole is even greater, we don't know exactly how much.

The force of gravity around a black hole is such that not only any massive object can not escape: even the light is trapped. In principle, the particles of light, photons, have no mass, but since they carry energy, one can attribute a mass to them, according to Einstein's relation $E = mc^2$. So the light of the stars, when it passes close to the Sun, is slightly attracted: the path deviates from the straight line. The effect

was observed as early as 1919 during the solar eclipse²³. The light that reaches the black hole is literally swallowed.

If the light that enters a black hole and no longer comes out, the ball made of such a heavy material looks completely black, as in "photo" 2.20a. Only recently we have acquired irrefutable proofs of the existence of black holes: gravitational waves, i.e. the distortions of space-time barely perceptible with the most sophisticated instruments of all (precision 10^{-23}). The first wave, recorded in 2015, is a proof of collision, or rather mutual swallowing, of two black holes with a mass of about 30 solar masses each, see fig. 2.20.

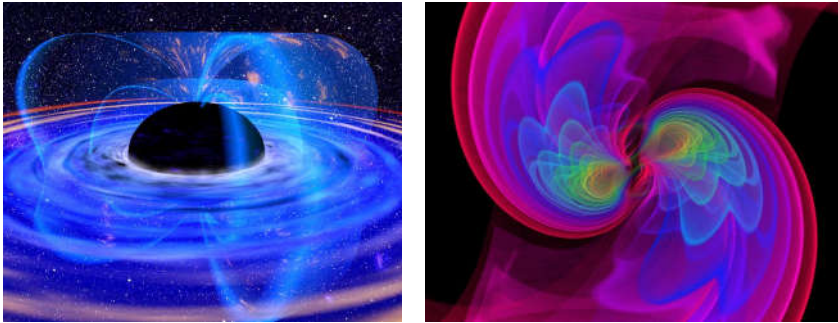


Figura 2.20. (a) A gravitational hole seen from the outside is a perfectly black sphere: no ray of light escapes from it; the strong gravitational field outside the hole accelerates matter and makes it glow before swallowing it. (b) The artistic reproduction, based on detailed calculations, of the collision of two black holes of 29 and 36 solar masses, recorded on Earth (14/09/2015) by gravitational waves, and occurred - at a distance of 1.3 billion light years. NASA Goddard Space Flight Center.

What does the matter inside the black hole look like? It is difficult even to call it matter: the extreme force of gravity crushes everything, including atoms. There will no longer be chemical elements – hydrogen, carbon, oxygen – but a mixture of neutrons, all identical. A black hole can perhaps be compared to a cauldron of even more exotic particles, certainly very, very hot.

Not only is the matter crushed, but inside the black hole also the time stops²⁴: one second becomes an eternity – in a physical sense, not

²³ The observation made during two English expeditions was not easy, but the answer proved Einstein's general theory of relativity right: the deviation from the line was twice as great as Newton's theory predicted.

²⁴ S.S. GUBSER, F. PRETORIUS, *The Little Book of Black Holes*, 2017, Italian edition *I buchi neri*, Le Scienze, Rome 2018.

just metaphorically. Without a doubt, a black hole is the end of all that is beautiful around us. So, children, rightly, are terrified of the black hole. Fortunately for us, those still revealed, which wander in space, are a few billion light years away from us.

The infinitely small

3.1. Man: an intermediate dimension

The entire Universe, which spans 13.8 billion light-years, is the largest structure we can observe. At the other extreme, the infinitely small, are the atom and its components. The dimensions of a human body are in the middle between the Universe and the atom.

The measure of man, a meter and something, has also become the measure of the world around him. This was the case even before the metric system: the English thumb and foot, the Tuscan cubit (elbow) (equal to 58.4 cm). The millimetre is the diameter of the head of a brooch, and one hundredth of a millimetre the thickness of a hair. The thickness of a soap bubble is one thousandth of a millimetre. The atoms, the elementary chemical structures, are still 10 thousand times smaller (in scientific notation: 10^{-10} m in diameter). For example, the radius of the electron orbit in the hydrogen atom is 0.53×10^{-10} m.



Fig. 3.1. The height of a man (1.7 meters) is located in the "middle" between the diameter of the Earth 1.3×10^7 m, photo of Apollo 17 and of our Galaxy (1.2×10^{21} m, here the photo of the galaxy IC342) on one side, and the atom (1.1×10^{-10} m) and the components of its nucleus (about 10^{-15} m) on the other. The Sun (with all planets) is part of a gigantic bun, about light years in diameter. It is our "Galaxy", in Greek Milky Way, one hundred billion stars that surround us. However, the Milky Way is one of 100 billion similar galaxies. The Universe available to our knowledge has a radius of 13.78 billion light years. In meters it is 1.3×10^{26} m. SOURCE: (a) D. WOS; (b) NASA, Apollo 17 Crew; (c) Wikipedia, Da_Vinci_Vitruve_Luc_Viatour.jpg; (d) https://en.wikiquote.org/wiki/Atomic_theory, (e) TOMASZ WRÓBLEWSKI.

Are there structures smaller than the atom? Yes, the components of an atom: the electron and the proton still have diameters a hundred thousand times smaller, equal to 10^{-15} meters. And then the constituents of a proton, the three *quarks* have dimensions of the order of 10^{-18} m, if we can still talk about dimensions, since we don't have a way to measure them. Physicists speculate on even smaller sizes, down to 10^{-34} m.

In the opposite direction, the circumference of the Earth is 40 thousand kilometres (and this was the original definition of the meter), the distance between the Earth and the Moon is 380 thousand kilometres (a spaceship arrives to the Moon comfortably in two days). We are 150 million kilometres away from the Sun (and this is called the "astronomical unit of measurement" – 1.5×10^{11} m). The Solar System spans something like 130 astronomical units.

But even the astronomical unit is not adequate to measure the extent of the entire Universe. Astronomers use the "parsec", based on the angle of observation. Physicists use a measure based on the speed of light, which is very high (about 300 thousand kilometres per second): a flash of light takes 8 minutes to reach us from the Sun. The light of the closest star, on purpose named "Proxima", in the constellation of Centaurus, requires about 4.5 years to reach us.

3.2. A-tomos, i.e. in-divisible

Georges Lemaître had hypothesized that the universe began from a single primordial atom¹. Thus cosmology is linked to the physics – this time not of an infinitely vast universe but of the infinitely small – of elementary particles. To retrace them, let's go back to the ancient Greeks.

A piece of Scandinavian rock granite contains crystals of three different colours that can be separated from it. A grain of sand, i.e. quartz, can be shredded into a white powder, used for domestic cleaning in the form of a suspension: a thick liquid for scrubbing floors (never stainless steel pots, because they will remain scratched!). These grains, almost invisible to the naked eye (one millionth of a millime-

¹ Equally interesting was Lemaître's observation that the notions of space and time had no meaning before the primordial atom split in two. Thus, space and time were formed a moment before the birth of the universe.

tre), can be further divided. Is there a limit to this fragmentation? Modern physics (or rather chemistry) answers - yes! It is an indivisible unit (by mechanical or chemical means) called the *a-tomos*, i.e. indivisible. Again in modern Greek *atomos* means a "person", that is, an individual.

It was probably Democritus (460-370 BC) who was the first philosopher to hypothesize the existence of atoms. According to his theory, all atoms are of the same size but differ in their shape, like the two letters F and L, even if by fitting together they can form compounds. The atoms were invisible, and they emitted "effluvia". What does modern physics (and chemistry) say? Even a hundred years ago, scientists, including Einstein, did not believe in the possibility of seeing atoms.

Today we know that all atoms are made in a very similar way with only two (or rather three, if the neutron is counted²) identical components: protons (in atoms heavier than hydrogen also neutrons), which form a small nucleus (diameter about 10^{-15} m), and electrons, which revolve around the nucleus about 10^{-10} m away³.



Figure 3.2. (a) A piece of granite from Latvia: large crystals of orthoclase (pink), quartz (white) and mica (black) can be distinguished. (b) The white crystals in the granite piece are made of quartz. On this photo, certain crystals are of the size of sand, others a thousand times smaller (about the size of a micrometre) are used to rub hostile dirt on hard surfaces. (c) Dividing the latter a thousand more times would lead to individual atoms, visible here through an "atomic force" microscope: the white dots are the atoms, while the black spaces indicate their absence. SOURCE: (a, b) Photo GK; (c) RHK Technology (2006), Dr Xue Kun, Prof. Xu Jian Bin – The Chinese University of Hong Kong.

² The neutron, discovered by James Chadwick in 1932, could be considered, in a first approximation, a sum of a proton and an electron.

³ An atom is almost empty. Comparing the nucleus of the hydrogen atom to an orange (diameter 10 cm), the electron spins 10 km away. Similar proportions characterize the Sun and the planets, including the Earth.

Strangely (or better: because of the laws of electrostatics) all atoms, regardless of their weight, from hydrogen to lead, are of similar size, about 10^{-10} m. Identical (governed by the same laws of the micro-world) is also the arrangement of the electrons (which form "orbitals", as in fig. 3.6 below).

For a few years now, there are direct methods of visualizing atoms, simple from a conceptual point of view but quite sophisticated from a technical one: a thin finger that goes on the surface of the crystal. The tip of the needle is so close to the surface that it is attracted by individual atoms. The force with which the needle is attracted to the surface is measured: the force is greater, if the atoms protrude from the surface. In photo 3.2c we show the surface of a silicon crystal, as in the electronic circuits of a mobile phone. The size of the individual points is about 10^{-10} m. If an atom is missing, the crystal is defective.

3.3. Efluids, i.e. photons

But matter is also visible for another reason: atoms emit a kind of "fluids" (using Democritus' term), that is, *photons*, particles of light. Depending on its energy, the photon changes its colour: violet photons are more energetic than red ones.

The processes of photon emission are closely linked to the structure of the atom, in particular to the number of electrons it possesses and the energy levels on which these electrons are located. This determines the different colours of neon, mercury or sodium lamps.

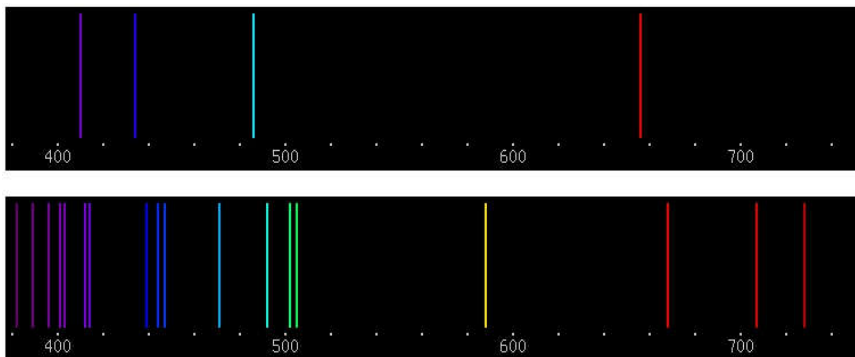


Figure 3.3. The emission spectra (visible light) of atomic hydrogen (above) and helium (below). On the abscissa the wavelength in nanometers. SOURCE: Wikipedia.

In figure 3.3 we see the colours (as separate lines) emitted by the hydrogen and helium atoms. In general, the more electrons an atom contains, the more lines appear in the spectrum: in Fig. 3.3 we count 4 visible lines for hydrogen (only 1 electron in different energy states) and 18 for helium (2 electrons). Atoms emit colours not only when they are heated (as in a flame), but also when they are simply illuminated. The visible colour of a body is the result of the processes of absorption and reflection of photons.

Thus colour is the imprint of a substance. Aristotle already sensed this in *De anima* (Book B7, "Sight") when he wrote:

The object of the view is the visible. Visible is the colour and also what can be expressed with a speech, but which is found to have no name: what we mean will be clear later. The visible is in fact colour, and colour is that which is on the visible for itself: I say "for itself" not because it is visible by its essence, but because it possesses in itself the cause of its visibility. Now, every colour is capable of moving the transparent that is in place, and this is its nature. Therefore colour is not visible without light, but every colour of each thing is seen in light. Therefore, it is necessary to say first of all what light is. So there is something transparent. I call transparent that which is visible for itself, but in order to express itself properly, not visible for itself, but by means of an alien colour. Such are air, water, and many solid bodies. (418a 26 – 418b 8)

What then is transparent and what light is has been said: light is not fire, nor in general a body, nor an emanation of any body (for in this case also it would be a body, but it is the presence of fire (or something similar) in the transparent. (418b 14–16)

Whether photons (Aristotle's "light") are bodies or not remains an open debate among physicists still today: photons possess mass, but only when they travel (at the speed of light). When they are stationary, they do not have mass, in fact they simply do not exist. And Aristotle was right about one more fact: the fire (i.e., heated atoms) emits light, but light is not fire.

The discourse on colours is found in *De anima*, not in *Physics*: in fact, colours as we see them are produced by physics, but ultimately by our brain. Of the seven colours of the rainbow, the human eye uses practically only three: red, green and blue. The three sensors in which human eye is equipped have their maximum sensitivity in these regions of the "spectrum", see figure 3.4a.

Bees see colours differently (see fig. 3.4b): green is grey, brown is black, they do not see blue (indigo; so there are no blue flowers pollinated by bees), while they see red, yellow and ultraviolet very well. In the white flowers of the apple tree illuminated by the sun, small bulbs light up in the centre, but only if the nectar is still there.

Aristotle understood well that it is the colours that carry the most information on objects and that only in the dark we must use the spare receptors of the eye, i.e. the so-called *rods*, for vision in shades of grey. The light visible to the human eye is only a part of the entire spectrum of electromagnetic radiation that comes from the Sun, which in addition to the visible includes the ultraviolet and infrared. From wavelengths of 0.1 to 10 micrometres of the solar spectrum we see only a narrow range of 0.38 (i.e. violet) to 0.76 micrometres (i.e. red).

It seems little, but 50% of the energy of electromagnetic waves that reaches the Earth's surface is included in the region visible to the human eye. In addition, all the gases in the atmosphere are transparent in this region of the spectrum. But even the dog does not see all the colours we see: for him, green is colourless. Then, it is not the eye that makes the image, but the human brain: from a million points ("pixels") it makes a complex picture. Insects, which are practically mindless, have an eye "composed" of hundreds of cells, of which each of them is a disconnected photoreceptor. Birds also react to a movement rather than a shape or the colour of the worm to be tasted.

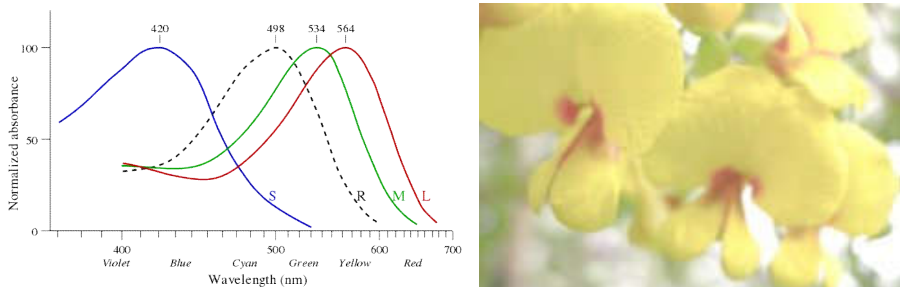


Figure 3.4. The sensitivity of the human eye (the three types of color vision cones) and grayscale vision rods. SOURCE: Wikipedia (Rod_cell). (b) A simulation of colour vision by bees. PHOTO: M. KARWASZ, GK image processing.

Unlike puppies, the baby looks at the world in the first minutes after birth. It takes a few days to understand that all the coloured spots are physical, palpable objects, then, stretching out his hand and touch-

ing his mother's face, (s)he begins to understand that the objects are three-dimensional, and by taking off his mother's glasses he realizes that certain parts of the face can be disassembled, others such as the nose are not.

The human eye, with hundreds of millions of receptors, colour vision, very high sensitivity and wide spectrum of colours is truly a wonder of Nature. Not to mention the human brain...

3.4. Why do we see colours?

The explanation of colour vision came only in the twentieth century and required a genius mind like Einstein's.

Ultraviolet light, even of minimal intensity, can cause cancer, because it carries enough energy to cut the DNA strand. But the phenomenon seems very strange, if we consider light as an electromagnetic wave: the energy of the waves depends first of all on their amplitude; on the same sea surface, a gentle breeze does not cause damage like a gale with gigantic waves. With light it is different: red light, even very intense, does not carry enough energy to cut DNA, ultraviolet light – even very weak – does.

The energy of light arrives in packets, called quanta, or photons. The energy of a single photon depends exclusively on the wavelength of light, i.e. its colour, according to the relationship $E = h\nu$, where the frequency ν of the wave is related to its length λ through the speed of light $\nu = c/\lambda$. In other words, the shorter the wave (i.e., ultraviolet light), the greater the energy carried by a single photon.

The relationship $E = h\nu$ (h is a physical constant introduced by Max Planck) was deduced by Einstein to explain the so-called *photoelectric effect*. At the turn of the nineteenth and twentieth centuries, it was observed that the surfaces of some metals lose their electrical charge if they are illuminated by light: the effect depends on the colour of the light, not on its intensity.

Clearly, the quantum of light hitting the metal surface throws up an electron. But from the wave point of view, the phenomenon is very strange. Someone has compared the photovoltaic effect to a sea port with anchored boats, delicately swaying on the waves. Suddenly, a boat makes a 20-meter high jump, falls back down and then everything returns to the quiet.

The effect depends not only on the colour of the light, but also on the type of metal: alkali metals, such as sodium and potassium, lose their electricity more easily, i.e. a blue light and not an ultraviolet one is enough. The human eye works in the same way: a quantum of light hits the retina and causes a minimal electrical current to go to the brain. But to see colours separately, you need several receptors. We have three, sensitive to red, green, and blue light, as in figure 3.4a. In detail, the sensitivity ranges of these receptors partially overlap: a joint red and green illumination appears to be yellow; The violet colour falls on the sensitivity edge of the blue receptor and, although violet consists of high energy quanta, it seems to us quite dim.

Obviously, we can assume that it was a blind evolution that formed three different receptors, which in a complementary way cover the range of light from red to violet: it is not the entire spectrum of sunlight but only 380-760 nanometres⁴. But in this narrow interval 50% of the energy is enclosed (it means information about the outside world). But the different and practically infinite colours, in addition to being useful because they carry information, are also beautiful: how a "blind evolution" did manage to create such a sophisticated eye?

3.5. Atoms with hooks

Atoms of different elements possess different numbers of electrons. The number of electrons determines in a unique way all the physical properties of atoms, such as their macroscopic state (solid, fluid, gas), hardness, evaporation temperature, colour, and also chemical properties: an alkali metal, an oxidizer, a neutral gas, etc. The variety of these characteristics is very wide: helium, the lightest noble gas, remains liquid even at a temperature of zero kelvin (i.e. 273.15°C); tungsten, a very heavy and hard metal, melts at a temperature of 3695 K and evaporates at 6200 K; carbon (light atom) does not melt, but evaporates directly from the solid phase (it is subject to sublimation) at 3915 K.

Atoms, like the two letters F, can "fit together", interchanging their electrons, forming so-called chemical *compounds*. A yellow sulphur

⁴ A range covering frequencies (equivalent to wavelengths) 1:2 is called "an octave" in acoustics, eight white keys on the piano keyboard. On the keyboard there are more than seven octaves (which we hear perfectly) but the eye only covers *an* octave of light. But the fact that it covers this octave and distinguishes colours remains a wonder of nature.

powder (see fig. 3.5b), crushed with a drop of mercury, forms a grey compound (red if it forms crystals), the mercury sulphate HgS (the mineral called cinnabar), see fig. 3.5c.

About a hundred different atoms that exist in the world of chemistry⁵, combined with each other, can give an infinite number of materials – rock crystals, metal alloys and organic compounds, on which life is based.

Atoms do bond to form molecules. They can do this in many different ways: by giving up (or receiving) electrons or by spinning some of them (the outermost ones) around two atoms. By combining oxygen atoms (with 6 external electrons, i.e. of "valence") with nitrogen (5 electrons) compounds of different stoichiometries and chemical characteristics are obtained.

For example, among the nitrogen and oxygen compounds, N_2O is an anesthetic and propellant in whipped cream. NO is colourless and NO_2 brown; both form the smog of car traffic. NO (which in very small quantities forms in the nose) stimulates breathing, while NO_2 is poisonous.



Figure 3.5. Compounds of atoms can have very different physical characteristics from their constituents. (a) Mercury, Hg , a heavy metal, is liquid at ambient temperature: when shredded with sulphur (b), it forms a grey HgS powder; in crystalline form HgS is a mineral called cinnabar, a bright red pigment (c). SOURCE: Author

Even the same atoms can form different structures. The carbon atoms, if they interchange three electrons, form a graphite – a very soft mineral, used in pencils – and exchange four of them, a diamond, the hardest substance of all (which, however, becomes graphite at a temperature of a thousand degrees), see figure 3.6.

⁵ In Mendeleev's table, which today (2024) contains 118 elements, only 80 are stable, from hydrogen (No. 1) to lead (No. 82).

The richness of chemistry, and of materials science, derives precisely from this extraordinary difference in electrical, chemical, structural, mechanical properties, which produces a small variation of certain "positions" of electrons. Chemists, as we explain later, call these well-defined, *quantified* positions "orbitals". In the carbon atom, in different chemical compounds, electrons can spin on different orbitals. Indeed, these orbitals depend on the atom with which the carbon atom forms bonds.

Then comes the crystallographic structure, which means the way millions of atoms form a grain. The piece of a steel remains soft, if iron atoms with the addition of a few percentage of carbon atoms form a cube ("regular") structure; on the other hand, it becomes very hard, when the crystal has an elongated shape.

Even the optical properties, meaning Aristotle's "transparency" and the colour "that comes" depend on the arrangement of electrons in atoms and molecules. A substance is "coloured" when it reflects (like sulphur) or absorbs (like a crystal of ruby) certain wavelengths of visible light.

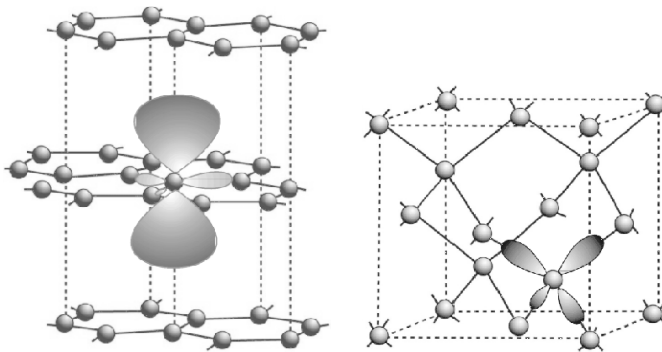


Figure 3.6. (a) The crystallographic structure of graphite: carbon atoms interchange 3 electrons. (b) The crystallographic structure of the diamond: the carbon atoms exchange 4 electrons. The atoms are marked as dots, and the "halos" represent "clouds" described by the inter-exchanged electrons. SOURCE: S. MITURA *et al.*, J. Achiev. Materials & Manufact. Eng, **16**, 1-2 (2006) p. 1.244.

The given lengths correspond to the particular "jumps" from one orbital to another that the electrons make inside the material. Visible light corresponds to the jumps (in our comfortable units) of a few eV

(electronvolts): more exactly between 1.65 eV (the red light) and 3.3 eV (the violet light).⁶

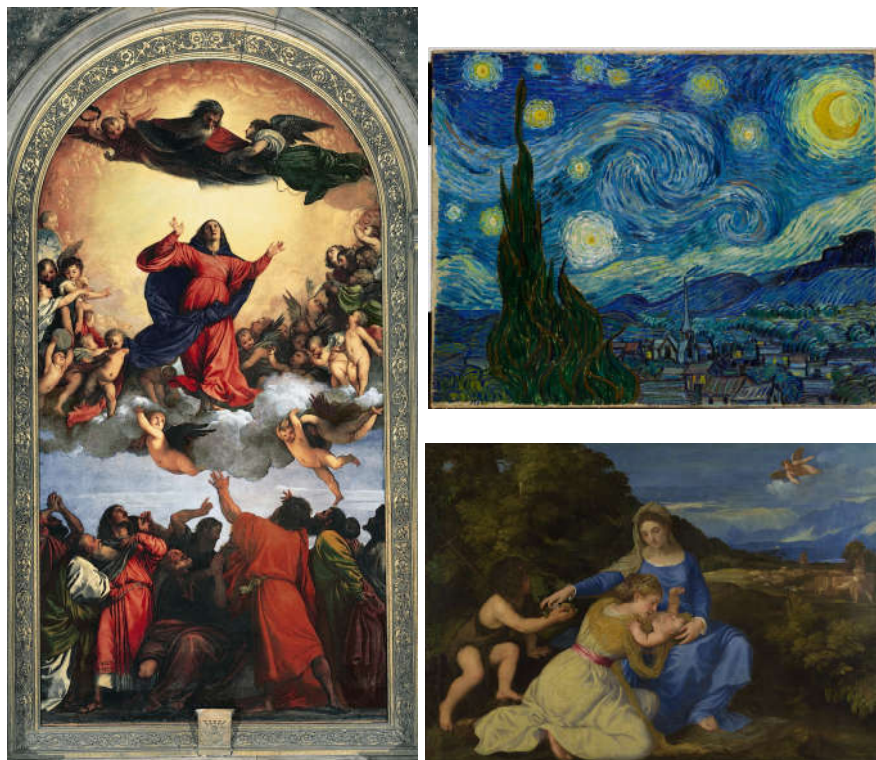


Figura 3.7. (a) Titian used the colour vermilion red (HgS) for the dramatic effect in the *Assumption of the Virgin* (Venice, 1516-1518): the red robes guide the eye towards the main characters. (b) Van Gogh used the least expensive pigments for the starry night: cobalt blue (CoAl_2O_4) and Prussian blue, a ferro-cyan. (c) For the robes of the Madonna Aldobrandini (1532) Titian used ultra-marine (lapis lazuli), an aluminum-silicate, a pigment more expensive than gold. SOURCE: Santa Maria Gloriosa dei Frari, Patriarchate of Venice, concession free of charge; Museum of Modern Arts, N.Y. & Scala Group; The National Gallery, London (permission gratis, educational waiver, with appreciation).

The levels of these jumps depend on many factors. The chromium atom gives a yellow colour in several chemical compounds but a beautiful red colour, when incorporated into a (colourless) alumina

⁶ For comparison, an electron inside the cell phone battery makes a jump of 3.7 eV passing from one lithium orbital to another, in two different "electrodes".

table develops by adding one electron at a time: atomic hydrogen H has one, helium He two, lithium Li – three, etc.

But why does the addition of an electron change the properties of an atom so drastically? This is determined by the position of the electrons in space. A single electron in the hydrogen atom spins on an orbit that can be considered circular; on this orbit we can put one more electron and no more. Two electrons on a fairly narrow circular orbit give a chemically non-reactive atom, helium. A third electron must occupy a new orbit, also "circular" but four times wider.

Thus the third electron (i.e. the outermost one in the lithium atom) is located far from the nucleus and easily "couples" with some electron of another atom: lithium is extremely reactive. The single electron of the hydrogen atom is also reactive: hydrogen in the gaseous state forms a diatomic molecule H_2 , and in the liquid phase, in acids, the hydrogen atom loses its electron and forms H^+ , which is the ion of all *acids*.

In beryllium, a fourth electron can still occupy a circular orbit. In boron (a light but hard metal), then in carbon, nitrogen, oxygen, fluorine, neon, the electrons occupy orbits one at a time in the shape of a double doughnut "8" (see fig. 3.9c). Three different positions (along three perpendicular axes) of these doughnuts are possible, so we can place 6 electrons. Gold is easily malleable, thanks to the particular shape of one of the outer orbitals, see fig. 3.9d.

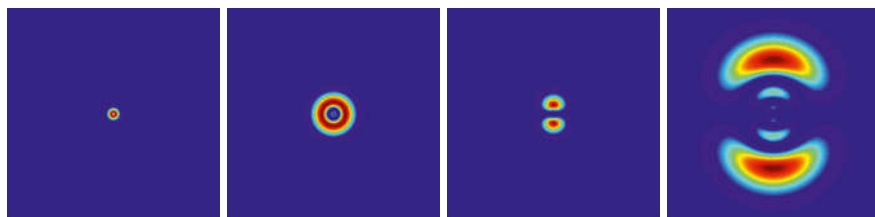


Figure 3.9. Solutions to the Schrödinger equation for a hydrogen atom (with a single electron): the shape of the orbitals: 1s, 2s, 2p, 4d. The red colour corresponds to the highest probability of finding the electron. SOURCE: K. FEDUS & Author.

We understood that the shape of the orbit and the odd or even number of electrons determines chemical properties. But we have not explained why more than two electrons cannot occupy the same orbit. In elementary chemistry this is explained by building squares, as in the game of naval battle: a single, a triple, a quintuple, etc. Then elec-

trons are added to the squares. Thus hydrogen is drawn as an electron in the 1s ("orbital") box, helium as two (with two opposite arrows, as will be explained shortly), etc., see Fig. 3.10.

The "tile" structure is just a picturesque representation of the mathematical solution of the equation that governs the motion (and positions) of electrons in an atom. These solutions are "quantized": not all orientations of the orbits (and electrons) are allowed. In each "box" two electrons are allowed. This is due to the rotation of the electrons: they spin on themselves, like the Earth around its axis. But unlike the rotation of the planets, the rotation speed of an electron takes on only one value, but with two directions (hence the up and down arrows). In this way, the two electrons are *distinguishable*. Then, on an orbital, i.e. in the single box in the schematic representation, a maximum of two electrons are allowed.

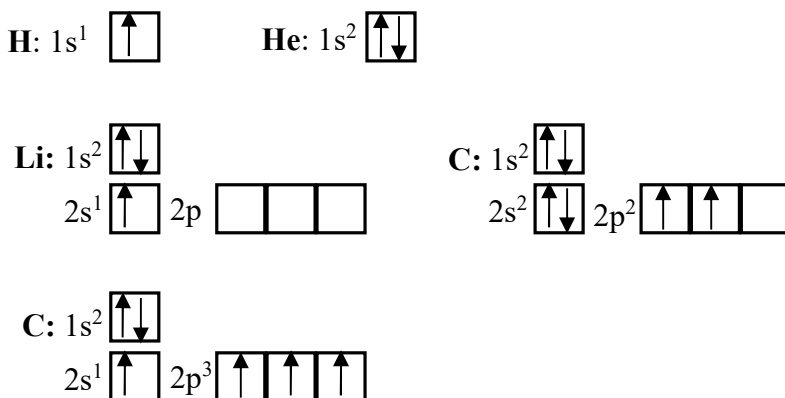


Figure 3.10. The electronic structure of atoms is described by "orbitals": in atomic hydrogen a single electron occupies the 1s orbital, in helium two electrons occupy the same orbital; in lithium the third electron is on the 2s orbital; two forms of carbon, graphite, with two electrons on the 2p orbital or diamond, with one electron of 2s and three on 2p. SOURCE: Author

This rule is called the Pauli "prohibition" (or principle). Let's reformulate this exclusion principle: at most two electrons (but with opposing proper rotations) can occupy the same orbital.

In the exact language of quantum mechanics it is said: "no more than one electron can occupy the same element of the phase space". In simple words, two electrons avoid each other, like two women in the same dress at the New Year's Eve ball. Because? No one knows. The

electron is small, light, without internal structure, so we can call it "elementary". But there are still many other elementary particles.

3.7. Bohr: An almost empty atom

Drawings of atoms, such as the one below (3.11a), are erroneous, for a couple of reasons. The first is that on the same type of orbital (circular in this drawing) the number of two electrons is the upper limit: the third electron rotates on an orbit, yes, circular, but much more distant. The second reason is the size of the atom and its interior, i.e. the nucleus, which are out of scale in the drawing below. The orbit of the electron (in the simple model, made by Niels Bohr in 1916), with a radius of 0.53×10^{-10} m, is a hundred thousand times (105) larger than the radius of the proton (0.88×10^{-15} m).



Figure 3.11. (a) The design of the atom, in the so-called Bohr model, is wrong for several reasons: there are not four circular orbits, but only two; then in general, the orbits are not well determined. (b) The electron (which revolves around the nucleus) behaves like a wave. Stationary orbits are just that, when the wave closes in on itself, like the decoration of this saucer in a café in Paris. (c) Planets, unlike electrons, revolve in the same plane (called ecliptic): the gravitational forces between the planets are attractive, between the electrons repulsive. Here the orbits are in the right proportions, but the Sun is larger. DATA SOURCE PROVIDER: E.G. BLACKMAN, University of Rochester; Author; Wikipedia (H. SMITH, L. GENEROSA), NASA.

By comparison, assuming the size of the nucleus to be about one centimetre, the electron (also with a radius⁷ of a few millimetres) would be one kilometre away. In other words, the atom is almost completely empty.

⁷ Unlike the proton, we have no direct way of measuring the radius of the electron. The limit set by the laws of classical physics (electrostatics and Einstein's special relativity) amounts to 0.28×10^{-15} m.

The Solar System is also almost empty: comparing the Sun (diameter 1.3 million km) to an orange, the Earth looks like a pinhead, placed at a distance of 10 m. But nothing prevents the planets from being closer to the Sun: Mercury, which is three times closer than the Earth, see fig. 3.11c, does not fall on the Sun, because (according to Kepler's laws) it simply spins faster than⁸ the Earth around it. What prevents an electron from being closer to the nucleus than the Bohr radius? Quantum mechanics, or rather quantum wave mechanics.

To explain his model of the atom, Bohr had placed a somewhat artificial condition on the orbit of the electron, according to which the product of radius r and the orbital velocity v are an integer multiple of Planck's constant, h .

$$mvr = nh \quad (3.1)$$

where m is the mass of the electron. It was an arbitrary hypothesis until another interpretation: quantum wave mechanics. In 1924 a graduate in history, Count Louis de Broglie, wrote a doctoral thesis in physics. In his work he assumed that the electron, like the photon, can sometimes show a wave-like nature. In fact, in the photocell of the mobile phone a photon behaves like a particle, in the rainbow like a wave (see fig. 2.9).

The wavelength of an electron, in de Broglie's model, depends on its velocity. And since this in turn must be in relation to the radius of the orbit (through Kepler's laws, which also apply to electric forces, not only to gravitation), Bohr's condition (3.1) is obtained: for a stationary orbit (i.e. so that an electron does not fall on the nucleus immediately), the wavelength must "close" on itself (see fig. 3.11b).

Other reasoning also leads to the result that the orbit of the electron is enormous compared to the size of the nucleus: in other words, the atom is mainly made up of a vacuum. What would happen if the electron stopped spinning and fell on the proton of the nucleus? The positive charge of the proton is cancelled out with the negative charge of the electron, and a particle is formed with almost the same mass as the proton, but electrically neutral, a neutron. Goodbye atoms! with all their chemical diversity: a set of neutrons is indistinguishable.

Can a set of neutrons exist? Yes, stars that end their lives can collapse: the force of gravity crushes atoms, electrons cancel out with

⁸ The planet Mercury completes a complete orbit in 88 days.

protons and all this forms a neutron star⁹. The Sun, composed mainly of hydrogen and helium atoms, becoming a neutron star would have a diameter of 11 km, that is, it would shrink by a factor of 10^5 , the same factor we calculated at the beginning of this paragraph for atoms. An atom, fortuitously for chemistry (and for us), is almost empty. And Bohr's postulates remain much metaphysical.

3.8. Schrödinger: The wave function

Max Planck, in order to explain the colours of the rainbow (i.e. the continuous spectrum of the Sun), had to assume that light was sent to portions of energy, called quanta. The narrow lines of the different colours, which emit the rarefied heated gases, show that the electrons in the atoms make "jumps" from well-defined, i.e., quantified, energy levels. Bohr was able to calculate these levels for the hydrogen atom, almost in perfect agreement with the observed lines. But his hypotheses were "postulates": quantum theory predicted certain phenomena, but failed to explain other experiments with electrons.

One of these experiments was the work of Carl Ramsauer published at the Technical University of Gdańsk in 1919. Studying the passage of electrons through rarefied gases (argon, krypton), he realized that at low energies the gases became completely transparent. At higher energies it was different: the gases remained almost impenetrable, see fig. 3.12a.

No wonder glass is transparent: that's just the way it is. No! glass is not transparent, neither for rubber balls nor for stones; it is transparent only to the light and only to the visible light: it is not transparent to infrared¹⁰ (hence the "heating" function of glass greenhouses), nor to ultraviolet (the "googles" remain imprinted on one's face when he/she tans with sun-glasses with glass, i.e. vitreous lenses). Light is a wave!

The Ramsauer effect has no explanation, except for the hypothesis that electrons are waves and that their wavelength depends on energy. By varying the wavelength, under certain conditions the gases become transparent. After de Broglie's work it became clear that the electron could be described as a wave. An equation was needed.

⁹ Only recently, in 2017, we observed gravitational waves due to the collision of two neutron stars: irrefutable proof of their existence.

¹⁰ Glass is essentially composed of silicon oxide, SiO₂. Crystalline silicon, Si, is metallic gray in visible light but is transparent in infrared.

The equation to describe a wave on the lake (or on the rope) has the form

$$\frac{\partial^2 y}{\partial x^2} = -c \frac{\partial^2 y}{\partial t^2} \quad (3.2)$$

where c is the velocity of propagation of the wave and t is the time, x means that the wave propagates along the x direction, and that the oscillations (up and down) go in the y direction (∂ is a variation either in the x direction or the variation in time).

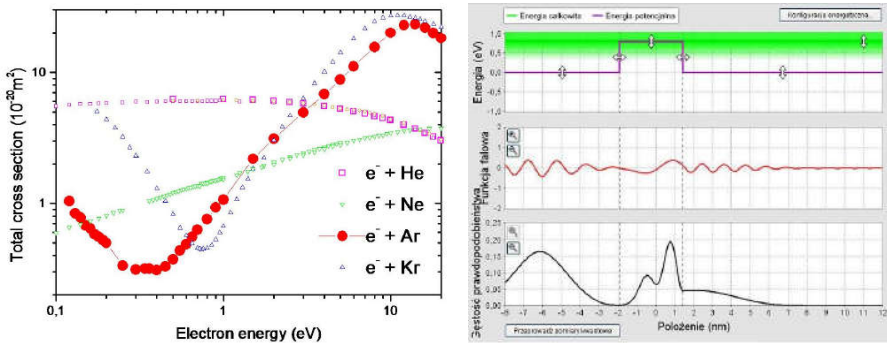


Figure 3.12. Physics of the Schrödinger's equation: (a) at a given energy the electron can pass through gases almost without obstacle (the minimum of the red curve indicating argon): the measurements of the "cross sections", i.e. the "dimensions" of the atom as a function of the kinetic energy of the electron. (b) Similarly, the electron has a certain probability (lower curve) of crossing the potential barrier (the upper rectangle). The red curve shows the wave function and the black curve (the lower panel) shows the probability of finding the electron: the electron can pass, it can be reflected but also trapped for a certain time inside the barrier. SOURCE: Author; PhET University of Colorado, simulation parameters by GK.

We don't have to go into mathematical details in order to understand that the electron equation (of mass m) is similar:

$$i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi}{\partial x^2} \quad (3.3)$$

The math is a bit more complex, using the imaginary number i , and the electron (i.e. its position in space and time) is described by the "wave function" Ψ . The constant $\hbar$ is used, i.e. Planck's constant h di-

vided by 2π (so it is better understood that the wave function of the electron in the atom closes on the complete circle, see fig. 3.11b).

The equation proposed in 1927 by Erwin Schrödinger, differs somewhat from the equation of waves on the lake (or light), for the reason that light (in a vacuum) always propagates at the same speed, but a free electron can be accelerate to any speed. The Schrödinger equation became our key to understanding the microworld.

The electron behaves like a wave not only when it passes through an atom: it is also reflected (and partially¹¹ passes) by a barrier, see fig. 3.12b. In its behaviour the electron (and other objects of the microcosm) differs from the bodies of the macrocosm, like the tennis ball. The latter, if hit below the edge of the net, will not pass: the electron can, with a certain probability, pass, even if it does not posses the (potential) energy greater than the barrier.

The probability of finding the electron in a given place is described by the wave function Ψ (or rather: by the "modulus" of this function, see fig. 3.12b). In classical physics it was possible to determine the position of a particle at any time; in quantum physics we only talk about *probability*.

Schrödinger's equation has created serious conceptual problems: an electron, a quasi-point particle, behaves like an extended wave: sometimes it passes over the barrier, other times it reflects (and for a certain time it is trapped inside the barrier). Physics has lost its classic certainty. Or rather: we have been prevented (by Schrödinger's equation?) from having this certainty.

3.9. Heisenberg: The certainty of uncertainty

The Schrödinger equation describes the position of an electron (or some other object in the microcosm¹²: nucleus, molecule, group of atoms) as a function of time. By treating an electron as a wave, however, it does not allow a precise determination of the position, but de-

¹¹ "Partially passes" is not an entirely correct statement: the wave function describes the *probability* that the electron will pass. In other words, it describes how many electrons, fired in a large quantity, pass through the barrier.

¹² Not only the electron is described as a wave, but also the tennis ball; except that for heavy objects (i.e. large masses in equation 3.1) the "wave" effects are small and classical mechanics is sufficient to describe their motion.

scribes a "probability distribution" (see Fig. 3.12b). In other words, we cannot know the location with "certainty".

This seems unreasonable: to know the position of a table it is enough to simply measure it - indeed it takes a "blink of an eye". But "blink of an eye" means sending a photon to the table and collecting the reflected photon. This operation does not affect the position of the table, but of a tiny¹³ electron it does!



Figure 3.13. (a) The objects of the microcosm on the macro scale behave like classical objects: in the "bubble" chamber an alpha particle (2 neutrons + 2 protons) collides with a (lighter) proton in the hydrogen atom: the angle of impact is acute. The photo also shows the Heisenberg principle; the traces are not continuous: where there is the point, the alpha particle has hit some electrons (then its position is well determined), but we do not know the direction and speed; Between two points we can deduce the speed, but we don't know the positions in between. (b) The objects of the microcosm behave like waves: a beam of electrons passes through two very narrow slits (made by an electric potential). Despite the fact that the electrons pass one by one, a "wave" image is formed on the screen, as if a subsequent electron knew where the previous one fell. Obviously, an electron does not "know", but is *governed* by the equation intuited by Schrödinger. SOURCE: H. HAKEN, H.C. WOLF, *Atoms and quantum*; Hitachi Ltd. (Youtube).

From an experimental point of view, in quantum mechanics the measurement influences the measured object. Mathematically, each different measurement means doing a different operation with the wave function. It turns out that even mathematically one measurement influences the other: if we have measured the position of the electron, we have changed its speed, then a subsequent measurement of the speed will be wrong.

¹³ The mass of an electron amounts to only 9.1×10^{-31} kg.

This principle was first noticed by Werner Heisenberg (1901-1976): some pairs of physical quantities, such as position and velocity, or energy and time, cannot be measured with a precision greater than Planck's constant $\hbar$, or rather $\hbar/2$, or $\hbar/4$ (theoretical physicists still discuss this).

Heisenberg's principle is often given a "magical" meaning: between one point and another in the electron trajectory we do not know what happens; the electrons in the experiment with two very narrow slits behave like a wave. Yes, they *behave*, but *they are not* waves. And the electron does not disappear between one collision and another, we simply have not *detected it*.

3.9.1. *Quantum cryptography*

The laws of quantum (i.e. wave) mechanics are counterintuitive: despite the better precision we cannot determine certain physical quantities; even knowing the position, we do not know the velocity (it is forbidden to know it intrinsically according to Heisenberg's principle), so we cannot *predict* the future position.

Mathematical dependencies between quantum objects lead to other paradoxes. By choosing two electrons from the helium atom (with their opposite spins), we can send messages that remain correlated even over great distances. So-called quantum cryptography is an absolutely secure way of sending messages: any attempt to spy on a part of the 0/1 series of the message completely deletes it. How does that work? Good question! In the words of one of the creators of this branch of physics, Paweł Horodecki, we are able to describe the mathematical formulation, encode messages, transmit and again decipher them, but we do not know how it works. Our intuition of the outside world simply ends here.

3.10. Skłodowska-Curie: Dividing the in-divisible

The atom is indivisible, but only mechanically. Already in the neon lamp, the electric current passes through the gas because a small part of the atoms lose their electrons. A reaction, taking as an example an atom of the main gas in "energy-saving" lamps – argon, Ar, takes

place in the electric discharge: an atom loses an electron (which has a negative electric charge) and forms an ion (with a positive charge)



The electrons are the particles that carry the electric current in the copper cable, they are the particles that draw the image on the screen of the old television (so-called "cathode ray tube"), they are the particles that, accelerated in the lamp ("magnetron") of microwave kitchens, generate the radiation that heats food (especially wet food). Their name means "amber" in Greek, since rubbed amber becomes "electrified"¹⁴, and consequently attracts powders.

Electrons are the main constituents of all matter and, as demonstrated by very recent experiments carried out on the Gran Sasso, they are stable (i.e. eternal): their lifetime exceeds the age of the Universe.

The Ar^+ ion, which is formed in the reaction (eq. 3.4), carries the positive charge, because the charge of protons, which form the nucleus, is positive. The argon nucleus contains 18 protons (the same number as electrons) plus a similar number of neutrons.

It was the Polish-born scientist Maria Skłodowska-Curie (1865-1925) who discovered that not only atoms but also their nuclei may divide. The first observation of such an event was made by H. Becquerel (in 1897), who noticed that the photographic plate blackened near the uranium salts. It was later discovered that uranium nucleus containing 92 protons and 146 neutrons (i.e. 238 neutrons and protons together) can be transformed into other nucleus (thorium, with 90 protons and 144 neutrons) emitting a particle composed of two protons and two neutrons (the so-called alpha particle, which is actually a helium nucleus). Schematically, taking into account the number of electrons and protons plus neutrons, we can write:

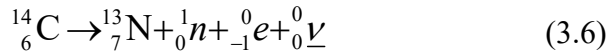


The more than a hundred years that have passed since the work of Maria Curie and Henri Becquerel have shown that only certain nuclei are stable, such as carbon with 6 protons and 6 neutrons. Carbon with 8 neutrons, called in short notation ${}^{14}\text{C}$, is formed in the atmosphere¹⁵

¹⁴ We do not know in detail how this process takes place, despite centuries of studies, starting with Alessandro Volta (1745-1827) and the invention of his "pile".

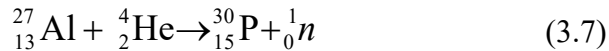
¹⁵ Nuclear device testing in the 1950s and 1970s contributed to the increase of ${}^{14}\text{C}$ in the atmosphere.

under the action of cosmic radiation and decays, halving its amount in 5730 ± 40 years. In the radioactive transformation of ^{14}C , one of the neutrons is transformed into a proton and an electron is emitted (plus a very light particle, difficult to detect, the neutrino, predicted by the Italian physicist Enrico Fermi). In a symbolic way we can write this reaction as:



where n stands for neutron (mass 1, charge 0), e – for electron (mass 0, charge -1), $\bar{\nu}$ – for anti-neutrino (mass and charge = 0). This decay, in which an electron is formed, is called *beta* - the name given to the rays emitted (i.e., electrons) when they were observed by Maria Curie.

In 1937 Maria Curie's daughter, Irène Joliot-Curie, and her husband Frédéric discovered that radioactive decay can also be induced. They observed that an aluminium nucleus absorbing the *alpha* particle turned into a radioactive phosphorus nucleus, emitting a neutron, according to the reaction



The phosphorus nucleus was radioactive and within a few minutes¹⁶ it transformed (by emitting an electron) into silicon, the isotope ^{30}Si . Man has fulfilled the old dream: to transmute one chemical element into another.

Why all these reactions? It is these processes that allowed the formation of all chemical elements inside the "nuclear ovens", that is, inside the star of the proto-Sun. And without these elements there would be no life and neither would we.

3.11. The energy of stars

Even a hundred years ago it was not known what the source of energy of the Sun was. In 1897 a famous physicist, Lord Kelvin (who invented the absolute temperature scale), blatantly misjudged the age of the Sun (dating it to just 50 million years), because he believed that the

¹⁶ The radioactive half-life of the isotope ^{30}P is 2.5 minutes.

source of its energy was its collapse (under the force of gravity). In fact, it was already known at that time that radioactive decays "produce" energy, as for example in the case of uranium, but not only: much more (with the same mass) is obtained from the synthesis of helium from two nuclei of heavy hydrogen, see fig. 3.14a:



Even if the two protons (in hydrogen atoms) repel each other (being two positive charges), at short distances the neutrons and protons attract each other. Since the net force is attractive, the helium nucleus is formed and a large amount of energy is released.

The situation is similar to falling into a ditch: you hurt yourself and the energy of the fall can damage your leg. In nuclear reactions this reaction is released, and ultimately turns into heat, a lot of heat.

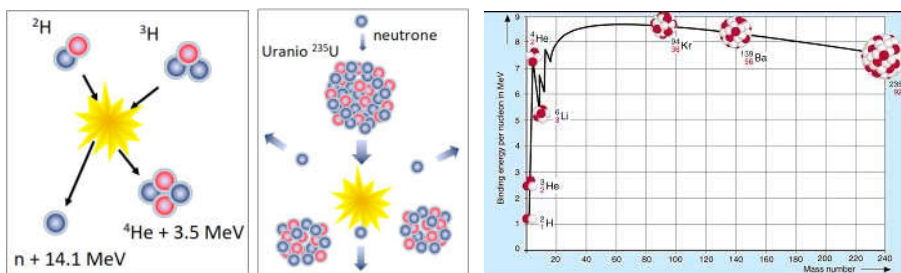


Figure 3.14. (a) The synthesis of a helium nucleus, as in the thermonuclear power plant (and in the heart of the Sun), takes place from two nuclei of heavy hydrogen (deuterium and tritium); a nucleus of helium, a neutron and 17.6 MeV of kinetic energy (meaning heat) are produced. (b) The splitting of the nucleus of uranium ${}^{235}\text{U}$ the nucleus absorbs a neutron and splits into two fragments of approximately (but not exactly) equal mass; two or three neutrons are also emitted and a large amount of energy is released. (c) The binding energy of nucleons (i.e. protons or neutrons) for different atoms from hydrogen to uranium: the most stable nucleus is that of iron ${}^{56}\text{Fe}$; the helium ${}^4\text{He}$ nucleus also remains particularly stable. SOURCE: (a, b) dr Tomasz Wróblewski; (c) European Nuclear Society.

If chemical reactions, such as the formation of the CO_2 molecule by burning coal, release energy of a few fractions of eV (electronvolts), the formation of a helium nucleus from hydrogen provides 14.4 MeV (a million times more).¹⁷

¹⁷ Obviously, according to $E=mc^2$, when energy is obtained in the synthesis of helium, the mass decreases, but imperceptibly (less than 1%).

Thus, in nuclear synthesis reactions (helium from hydrogen, carbon and oxygen from helium¹⁸, etc.) an enormous amount of energy is released: this is the mechanism that allows stars to shine, and our Sun to maintain life on Earth.

But there is a "but": the synthesis of heavy nuclei takes place up to iron; after iron, synthesis is no longer advantaged from an energy point of view. Very heavy nuclei become unstable; their splitting is energetically favoured. We report these observations in graph 3.14c. From hydrogen to helium (i.e. the low numbers on the mass axis) the curve rises: heavier nuclei have a higher binding energy. Beyond the iron the curve goes down: it means that the binding energy (referred to a single proton or neutron) goes down.

Why this dependence? We don't know in detail: it has been observed experimentally. Why don't we know how to calculate it? Because quantum mechanics works well for the hydrogen *atom*, where the binding energy is 13.6 eV; while for nuclear physics the energies become mega-electron volts (MeV) and require much more complicated calculations than current methods allow.

The curve presented in Fig. 3.14c is the key to the appearance of the Solar System: there was the collapse of a star, the formation of heavy nuclei in an extremely hot oven as the neutron star, the explosion of the supernova, and only later the "coagulation" of the ejected matter in the form of planets (comets, satellites, etc.). In this way, heavy elements such as zinc, selenium, copper, uranium, etc. were formed.

First three from the above mentioned elements are part of our metabolism, and uranium is indispensable to keep volcanos emit CO₂, and therefore maintain the climate on Earth enough warm for the biological life. The large amount of iron formed in the proto-Sun (and condensed in the centre of Earth) is essential for the existence of the magnetic field on our planet. And this, again, is important for higher forms of life.

We will speak about all these "coincidences" in Chapter IV.

¹⁸ The carbon synthesis reaction takes place with an intermediate stage of beryllium, see fig. 9.4 in the concluding chapter of this book.

3.12. "Elementary" particles

Until the middle of the twentieth century, the world of subatomic particles contained: the electron with the negative charge¹⁹ of value $-e$, the proton with the positive charge $+e$, the neutron with the zero charge. Of all three particles it was also known that they were characterized by their own rotation²⁰ (*spin*), which in the "atomic" units amounts to $1/2$ for them. At that time physicists believed that the electron, proton and neutron were "elementary" particles-cells, i.e. no longer divisible, and this was the result of studies of radioactive decays and nuclear reactions.

Some doubt arose from the fact that in some decays (called *beta-minus*) a neutron splits into a proton and an electron, while in other very similar decays a proton splits into a neutron and an electron with a positive charge, called a positron. This electron with the positive charge was theoretically predicted, as an unintended result, of the Dirac (1902-1984) equation.

After the discovery of induced nuclear reactions, eq. (3.7), it was decided to create special reactors, see fig. 3.15, which can "inject" protons (or alpha particles) into other nuclei.

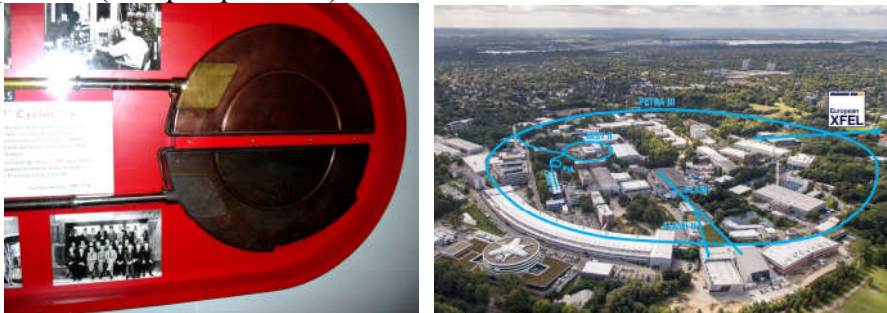


Figure 3.15. (a) The first proton accelerator, the synchrotron (here – built in Cambridge) was of the dimensions of a table. (b) Today's accelerators, such as the Hamburg synchrotron, are long hundreds of meters, if not tens of kilometres, like CERN accelerator in Geneva. SOURCE: GK; (C) DESY, Hamburg, 2015.

¹⁹ Where the charge of an electron is $e = 1.6 \times 10^{-19}$ C: if the current of 1.6 Ampere (typical of a washing machine) passes through an electric cable, these are 10^{19} electrons per second.

²⁰ The principles of conservation also apply to spin: the decay of a neutron into a proton plus an electron seemed to violate this conservation, so it turned out to be necessary the existence of the neutrino, which in addition to the missing spin carried the energy that seemed to be missing in beta decay.

Thus, in 1934 the first "accelerator" was built, that is, an apparatus to accelerate charged particles, such as protons (which, remember, are hydrogen nuclei) at high speeds. As in a neon tube, the electrons in the electric discharge, accelerated by the 220 V mains voltage, collide with the argon atoms and take away an electron, so it was supposed that protons (or electrons) accelerated by voltages of millions of volts, could fragment nuclei. With the construction of the first accelerator (photo 3.15a) the way was opened for a myriad of reactions, well controllable unlike the reactions induced by cosmic radiation.

It was soon discovered that there are not only positively charged electrons but also negatively charged protons (antiprotons). Several questions immediately arose: what are they made of? Is the neutron made of a proton plus an electron or the proton of a neutron and anti-electron (positron)? And what happens if an antiproton joins an anti-electron? Is an antihydrogen atom formed? Identical or not to a hydrogen atom? Anticipating the times, we can say that these are among the most urgent questions in physics today and whoever manages to answer them will take the Nobel Prize.

3.13. Invisible, penetrating, dangerous, beneficial

Nuclear radiation, like the *alpha* particle emitted in the reaction (3.8) carries energy, and for this reason it can ionize not only atoms (reaction 3.4) but also more complex molecules such as DNA. In nuclear reactions, not only particles are emitted, but also energy, in the form of electromagnetic waves. But unlike the neon lamp, in which visible electromagnetic waves (i.e. light) are created, in nuclear reactions, gamma waves, which are much more energetic, are emitted. To give an idea, red light has an energy corresponding to 2 eV (i.e. the energy of an electron accelerated by the voltage of 2 Volts), gamma quanta can have 2 MeV (million eV) and in the deep cosmos even 2 Giga (billions eV, GeV).

The sources of radiation are different: radioactive decays in the earth's crust (this makes the crust still liquid, 4.5 billion years after its formation), radioactive atoms in materials used for construction (concrete), a radioactive radon gas that is formed in the decay of uranium (therefore it comes out of the subsoil, especially in post-volcanic soils), energetic particles that come from the centres of distant galaxies, the Sun itself, etc.

rays (a few Å, i.e. $0.0001 \mu\text{m}$) up to *gamma rays*. It is difficult to establish the lower and upper limits for these wavelengths.²¹

The human eye sees only a small part of the spectrum of electromagnetic waves (but its cognitive capacity remains a wonder of nature). With special antennas we can scrutinize both the distant and the nano-scopic Universe. Practically nothing escapes us of the entire spectrum of particles, nor of radiation: except for this, which *we do not know*...

Without a doubt, we are immersed in an *ocean of invisible waves and particles*. The discovery of millimetre waves that pervade the entire cosmos has helped to provide decisive arguments regarding the knowledge of the beginning of the Universe. More on that later. But first, let's conclude the description of the elementary particle zoo .

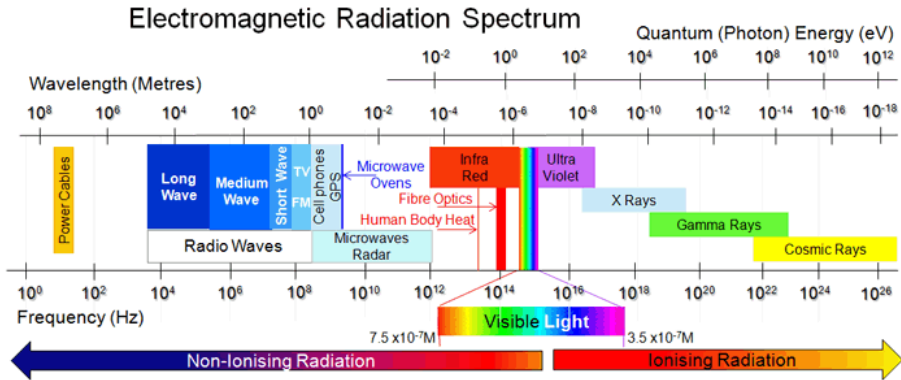


Figure 3.17. The spectrum of electromagnetic waves, from radio waves, longer (but less energetic), and microwaves, to X-rays and gamma rays of cosmic origin. Visible light, between 760 and 380 nm (which corresponds to an energy of 1.6 to 3.2 eV), is a small part of the entire spectrum. SOURCE: Woodbank, <https://www.mpow-eruk.com/images/emspectrum.gif>.

3. 14. Gell-Mann: quarks

If *alpha* decay, reaction (3.5), is easy to explain as a cleavage of the nucleus (even if one of the fragments is tiny in comparison with the other), *beta* decay (3.6) requires a transformation. It was also discovered that, in addition to beta decays in which the neutron seems to

²¹ For example, gravitational waves, which are not electromagnetic, have a wavelength of thousands of km.

transmute into a proton plus an electron, as in potassium ^{40}K (contained also in our blood), there are nuclei that decay in the opposite way: a proton turns into a neutron and a positron. In this way, the old sense of being "made of" no longer applies. Although a neutron is slightly heavier than a proton, the sum of the masses of decay products does not correspond to the mass of the original particle²². This is where Einstein's famous formula of energy and mass equivalence comes into play: $E = mc^2$. The missing mass of the constituents is balanced by the surplus of energy, and also vice versa: by absorbing the energy, heavier objects can be created from constituents that together would not have sufficient mass.

Two Polish researchers, M. Danysz and J. Pniewski, in 1951 observed a collision of cosmic radiation in a photographic plate, which produced a particle similar to the proton but unstable²³; it has been called "strange". In a few years, dozens of strange particles were discovered, which seemed to form families.

In 1963 two theoretical physicists, Murray Gell-Mann and Georg Zweig, advanced the hypothesis that neither neutrons nor protons were elementary particles but complex objects, consisting of three minor components, of two types: a positive particle, with an electric charge of $+2/3$, and a negative particle, with a charge of $-1/3$, which were called "quarks" by Gell-Mann²⁴. The positive quarks were called *up*, the others *down*. Thus, a proton is made up of two *up* quarks *up* and one *down*, while the neutron is made up of two *down* and one *up*. The decay of a neutron into a proton in the *beta reaction* consists in the change of a *down* quark into an *up* quark with the emission of an electron (and an anti-neutrino):

$$udd \rightarrow uud + e^- + \bar{\nu} \quad (3.9)$$

²² The mass of the neutron (as already mentioned) is $m_n = 939.5654133(58) \text{ MeV}/c^2$ (c is the speed of light needed for the conversion of a unit of measurement, the parenthesis indicates that the uncertainty is only on the last two digits reported). The mass of the proton $m_p = 938.2720813(58) \text{ MeV}/c^2$ and the mass of the electron $m_e = 0.5109989461(13) \text{ MeV}/c^2$. Thus, $m_p + m_e < m_n$. The mass of the neutrino is not known but certainly very small, of a few eV.

²³ The lifetime of a proton, estimated by several experiments, exceeds the age of the Universe.

²⁴ Murray Gell-Mann explains the origin of the name "quark" as follows: "In 1963, when I called these particles 'quarks', the first thing that came to mind was the sound of a word that could have been *quo:k*. Then, on one of my occasional readings of James Joyce's *Finnegans Wake*, I came across the word 'quark' in the phrase: Three quarks for Muster Mark." M. GELL-MANN, *The quark and the jaguar. Avventura nel semplice e nel complesso (Adventure in the simple and complex)*, Bollati Boringhieri, Turin 2000, p. 211.

and beta-plus *decay* (in which it forms into an electron with the positive charge, i.e. a positron) in the reaction

$$uud \rightarrow udd + e^+ + \nu \quad (3.10)$$

where ν stands for neutrino (small neutron, as it was called by Enrico Fermi) and $\bar{\nu}$ for anti-neutrino.

The *u* and *d* quarks, constituents of neutron and proton, are very light, with a mass of about²⁵ $2.3 \text{ } (^{+0.7}_{-0.5}) \text{ MeV}$ e $4.8 \text{ } (^{+0.5}_{-0.3}) \text{ MeV}$ for up and down quarks. Here the strange mathematical formula of $E = mc^2$ appears again: $2 \times 2.3 + 4.8 = 938.3$. We don't know why such light quarks can form very heavy protons.

The *down* quark itself is unstable: a free neutron, i.e. outside the atomic nucleus, decays (into a proton and an electron) after about 15 minutes: we don't know why. Nor are we able to explain why the masses of quarks take on these certain values. It is assumed that these exact values are essential for the stability (indeed the very existence) of both atoms and stars. We will talk about this more.

The discovery of the other, unstable "proton", made by Danysz and Pniewski, however, indicated that there is still another, third quark, with a negative electric charge, but heavier than *down* and with a very short lifetime: it has been called *strange* quark. A positive quark was missing to form the pair with the *strange*; it was discovered in a measurement competition between two American laboratories (Stanford and Brookhaven) and called *charm*. The *strange* quark (in a compound with up antiquarks, called kaon, *K*) lives just 10^{-8} seconds (in combinations with other quarks even less) and its mass is $95 \text{ MeV}/c^2$ (also for this there is no explanation). The charm quark has a mass of $1290 \text{ MeV}/c^2$; a *charm* compound with its anti-quark, i.e. a particle called J/Ψ , lives an unbelievably short time, 10^{-20} s. There is still a third pair (generation) of quarks, even heavier and even less stable. But we do not know the reasons for these three "generations" and their characteristics.

There are still many unknowns in the quark world. We are not able to predict their lifetimes or their masses; we don't fully understand why they form only two types of compounds: anti-quark quark pairs (such as the J/Ψ meson or the K meson) or three quarks ensembles (such as neutron, proton and their equivalents with heavier quarks).

²⁵ The numbers in the brackets describe the uncertainties more and less.

In the neutron and proton, quarks are bound with forces, which increase with distance; an attempt to separate them beyond the size of the proton (10^{-15} m) requires a force equal to that required to raise a car. This is how we talk about trapped quarks: no experience has highlighted single quarks.

Some theories (which, however, lack experimental verification) predict that at very high temperatures (10^{14} K) protons, neutrons and mesons can "melt" in a plasma, or in a "soup" of free quarks. No doubt, these forms of matter would be very exotic, *disordered* and *unstable*, not at all similar to normal matter ("earth", using Bible's language). Some astrophysical speculations even predict stars made from free quarks (small but very heavy stars: maybe black holes?), but again experimental indications are lacking.

The discovery of the three generations of quarks (of which only the first, lighter, is stable), with their increasing masses, led physicists to the idea that they were approaching first moments after the Big Bang.

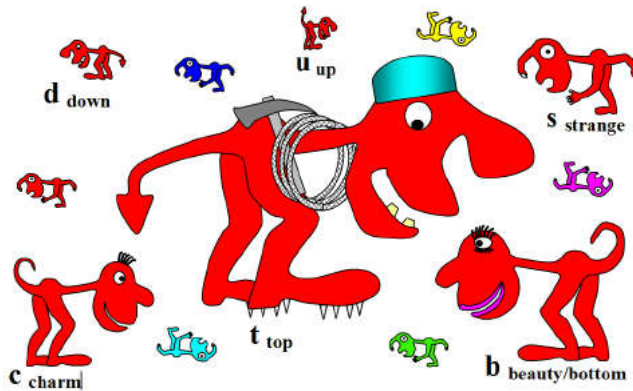


Figure 3.18. The three generations of quarks, according to Dr. T. Wróblewski: 1) the first, lighter, existing in matter (today, i.e. normal) formed by two quarks: *up* and *down* (look at the tail); 2) the second, heavier and more unstable (it lives no more than a billionth of a second) formed by *strange* and *charm*; 3) the third, *bottom* and *top*, was discovered in collisions in giant particle accelerators in the USA. The direction of the nose indicates the sign of the electric charge (positive right); the dimensions correspond (their fourth power) to the mass. Quarks can be of 3 colours (red, blue, green); moreover, there are anti-quarks with the same mass but with the opposite electric charge and the additional "colour" (the anti-quark of green is magenta, etc.). Behind these simple visualizations stay difficult quantum theories.

The large masses of *strange* and *charm* quarks, which correspond to their great energy (again according to $E = mc^2$), can be compared to

large temperatures: not of millions but hundreds of billions of degrees. Then, these quarks disintegrate into millionth fractions of a second. Thus, by reproducing heavy quarks in particle accelerators, we reproduced the conditions of the Universe in the first second of its life. At least, the physicists are convinced of this...

3.15. Weinberg: The first three minutes²⁶

The various nuclear decays, the reactions in the nuclei induced by bombarding with other particles, the infinity (today a few thousand) of possible agglomerates of six quarks and six anti-quarks: all this indicates that the presence of hydrogen and helium atoms in stars (the source of life on Earth) can be by no means taken for granted. In addition, the proportions between hydrogen and helium that we observe today were "defined" in the first three minutes of the history of the universe.

We have seen that the hydrogen atom is composed of a proton in the centre (nucleus) and an electron spinning around at great speed (1/137 of the speed of light). The electron and proton attract each other, but the laws of quantum mechanics prevent the electron from getting too close to the proton: their minimum distance is about 1/2 angstrom ($1\text{\AA}=10^{-10}\text{ m}$). If the electron fell on the proton, it could form a small neutron²⁷, with no electric charge. This happens in old, massive stars, which are composed only of neutrons: hot but already dead stars.

But all chemistry depends on electrons revolving on different orbitals, what allows atoms of metals, gases, etc., to be distinguished. In contrary, as we already said, in matter composed of neutrons no variety is possible, either chemical or biological. What were the mechanisms by which the matter did not collapse into neutrons in the first minutes of the universe? The most common answer is: because the values of the physical constants are "right". How did it come? We will return to this question in Chapter VII.

²⁶ For further information, we recommend the exceptional book by Nobel Prize WINNER S. WEINBERG, *The First Three Minutes. L. fascinating story of the origin of the universe*. Mondadori-DeAgostini, Novara 1994.

²⁷ A neutrino still comes into play, but we do not know precisely its properties or its function.

The physical models of the first instants of the universe are quite complex and are based on the properties of elementary particles discovered by means of large accelerators. On the other hand, these models have made it possible to predict various characteristics of today's universe, such as the proportions of hydrogen to helium, the content of heavy hydrogen, the ratio between the number of nuclear particles (protons and neutrons) and the light particles (photons) that wander in space.

The universe at the beginning was very hot, very dense and very small, although the first moment we can imagine is the universe already a few thousand light years in size. The hot universe means that the particles were moving at great speed, that is, their energy was very high. From Einstein's relation $E = mc^2$ it emerges that this kinetic energy of theirs could be transformed into other particles (or more precisely into pairs of particles with opposite electric charges, such as the electron and the anti-electron, i.e. the positron). On the other hand, particles annihilate with their own antiparticles, producing radiation, which again, colliding with other particles create new pairs, and so on. In its early stages, the universe was composed of this strange "soup" of particles, very exotic and radiation. This stage would have lasted forever, if the universe had not expanded immediately, causing a drop in temperature.

As the temperature dropped, it gradually became impossible to create particles above a certain mass. Thus protons and neutrons could be created and remain in mutual equilibrium, only up to 0.01 seconds after they began. From this moment on, the number of neutrons began to decrease: they, being unstable by nature, decayed into protons and electrons.

A famous Russian theoretical physicist (and a great friend of ours, Professor Lev Pitaevski), when asked why the masses of quarks, protons, electrons are so strange and seem to follow no logic, replied: "There are scientists who say that if these masses had been different, we would not have existed." A more exact answer cannot be imagined. As far as the masses of two *up* and *down* quarks are similar, the third quark is 20 times heavier. If the masses of proton and neutron are equal to 0.1%, the electron is 1837 times lighter (and "weighs" $0.51 \text{ MeV}/c^2$). The neutrino, which accompanies the electron as a product

of the neutron's disintegration, has the mass of a few²⁸ eV/ c^2 . These differences allowed the first three minutes of the universe to go "in steps".

First, the synthesis of protons and neutrons, which took place through the collision of photons (in 0.01 s), stopped; then (in 0.1 s) the creation of electron-positron pairs also slowed down. After the first second, neutrinos decoupled from matter; in this time a part of the neutrons already underwent decay: the ratio between the number of neutrons and protons is 1 to 3.

After 14 seconds, the electrons annihilate copiously with the positrons, producing a massive amount of photons (today there are a billion photons for an electron left in space). Only a part of the electrons survives, which corresponds to the number of protons (the electric charge of the Universe is zero, or at least we are convinced that it is).

At this temperature (3×10^9 K), neutrons and protons can bind into helium nuclei (binding energy 24 MeV) which has allowed neutrons to survive till our times. The excess protons remain as future hydrogen nuclei, and a very small amount of neutrons (a few parts per million) survive in the form of heavy hydrogen nuclei, deuterium²⁹. As Stephen Weinberg writes, exactly three minutes and 46 seconds have passed since the beginning of the universe³⁰. The composition of matter was fixed³¹, except for future reactions, now measured in millions and billions of years, in the cores of stars (and in the laboratories of scientists).

In summary: only electrons are elementary particles. Protons, composed of three quarks (*uud*) are stable; Neutrons, on the other hand, composed of the same quarks (*udd*), are unstable, except for those bound in atomic nuclei (or neutron stars). We have understood that the world of elementary particles is complicated but we know their characteristics with great precision. We don't just know, as always: *why*?

²⁸ The neutrino mass is not yet (in 2019) precisely determined.

²⁹ Deuterium is also found in water molecules in the oceans. It will be used to power thermonuclear reactors for the energy of the future. The resources are enough to ensure energy for the whole of humanity for the next 3 thousand years.

³⁰ S. WEINBERG, *op. cit.* p. 125.

³¹ Helium makes up 25% of the weight of the universe, the rest is essentially hydrogen.

3.16. Black and white television

My father bought the first television around 1966: it was a heavy and elegant wooden box, with a Cyrillic inscription “РУБИН” (RUBIN). After pressing the right button, it turned on behind a small bulb, then others and finally the box began to make a dull noise and a fairly regular picture appeared on the screen, with many small white and grey patches. After long attempts, one could synchronize the antenna and see a program. I was always curious what image had been encoded with those patches. I understood it many years later: it is the information that the universe sent us as soon as it was born; more precisely, 380 thousand years after its beginning, electromagnetic noise in the frequencies typical for microwaves (i.e. also television waves).³²

The entire Universe at that time was the size of our Galaxy, still very dense, like the sodium vapours in the yellow lamp used to light the streets. The spectrum of the sodium lamp should thus consist of narrow lines, like that of helium and hydrogen. In particular, sodium emits yellow light at 590 nm. But the street lamp does not work like that: where there should be two yellow lines, one next to the other, there is a large hole, as if the yellow light were trapped inside the vial with sodium vapours.

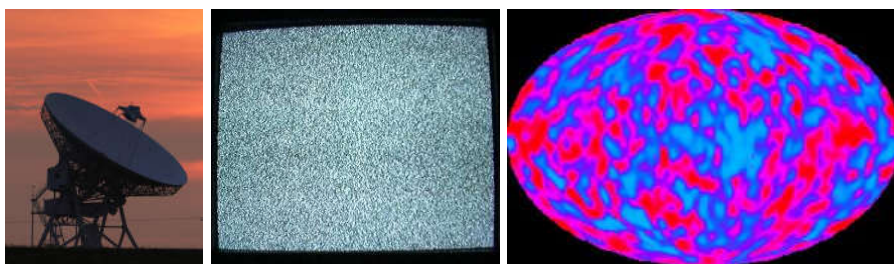


Figure 3.19. (a) In observations of the sky with radio telescopes (such as this one in Toruń) a persistent signal has been detected coming from all directions. (b) The same signal is picked up by an old black and white TV. (c) In detail, scanning the sky, very small differences in the temperature of this signal (i.e. microwave radiation) are observed; that distribution corresponds to today's galaxies and is the first signal of the newborn Universe that we can detect. A. ROMAŃSKI, UMK; GK; ESA.

This was also the case in the Universe 380 thousand years after its beginning: it was still hot (at temperature of about 3 thousand K), but

³² Of course, much of the noise on the screen comes from the TV's electronic circuitry; According to various estimates, only 20% of this noise comes from cosmic radiation.

also very dense. The light emitted by the hot atoms was immediately absorbed by other atoms; the universe seen from the outside seemed black. Then, when the density of the Universe dropped, light suddenly came out of matter. There is no better representation of this concept than the mosaic in St. Mark's Basilica in Venice, fig. 3.20b.

At the moment of decoupling between light and matter, the temperature of the universe was about 3000 K, which corresponds precisely to orange-yellow light, with a wavelength of a few fractions of a micrometre. Then, the universe expanded a lot and the wavelength also increased, which today is about ten centimetres, right in the domain of TV waves, and corresponds to the temperature of 2.3 K.

The "background" radiation was discovered by chance, in 1964, by two American technicians, Arno Penzias and Robert Wilson, in charge of building a large antenna for communications with artificial satellites. They observed a strange noise coming from all directions. Today we know that this radiation is the relic of the very young universe. The existence of this radiation is also irrefutable proof of the Big Bang.

Unfortunately, once the idea of the Big Bang has been established, several difficulties remain. Given the equivalence $E = mc^2$, energy can be created at the expense of mass and vice versa, the question arises: where did all this almost infinite mass (and energy) of the universe come from?

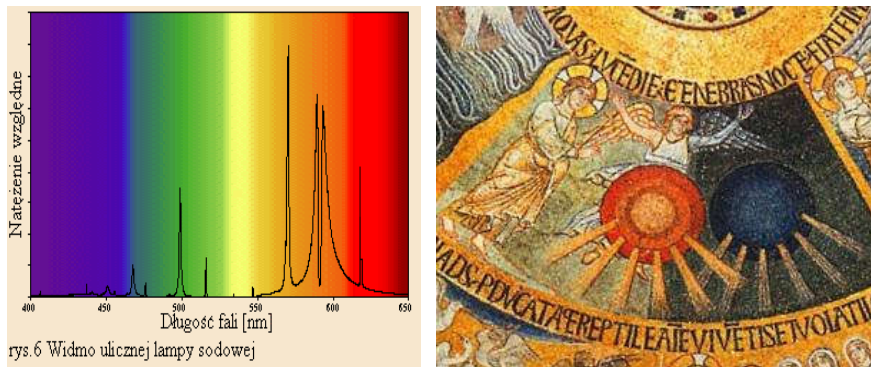


Figure 3.20. (a) The spectrum of a yellow street lamp (sodium vapour) shows a hole in the orange colour area: the vapours are dense, so the light does not come out of the sodium container (spectrum - GK). (b) The ingenious presentation of the light coming out of the dark universe: the yellow colour corresponds to the temperature of separation of matter from electromagnetic radiation. SOURCE: St. Mark's Basilica, Patriarchate of Venice, by kind permission, image: Kina Editions.

3.17. In the blink of an eye

The "first three minutes" model, as described in Weinberg's book, is the result of decades of studies in nuclear physics and elementary particles. Large accelerators have made it possible to create exotic, very unstable, and massively large particles, which translated into temperature terms correspond to billions of degrees. Obviously, in terms of Galileo's physics – of *repeatable* experiments with falling bodies – the Big Bang does not fall within the canons of verifiable scientific theory: we cannot repeat the Big Bang in its complexity. However, all physicists agree (i.e., believe) that the beginning of the Universe was just like that.

But there is a problem, or rather three. The first is the uniformity of the laws of physics: the spectral lines of hydrogen in the galaxies farthest from us, i.e. 13 billion light-years (both in terms of temporal and spatial distance), are exactly the same (with the obvious redshift due to the Doppler effect), as in the lamp in the Toruń laboratory. The Big Bang alone, with the Universe expanding rapidly, was not supposed to guarantee this uniformity of the laws of physics. There was no time to tune the farthest corners of a universe to the same physical laws and constants.

The second problem arises from the uniformity of the background radiation. In all directions of the Universe the temperature of this radiation is the same (and small differences roughly correspond to the distribution of today's galaxies). On a large scale, thousands or millions of light-years, there is no mechanism to achieve this *thermal equilibrium* observed in the entire Universe. That is, there must be a moment in which the temperature could have been uniform in the still very young Universe. What was the mechanism that did not violate the limits of propagation of material signals discovered by Einstein?

The third problem, the most serious of all, is the mere existence of the universe. To allow the decomposition of primordial quarks into modern quarks, the coupling constants (which we know only from experiments) had to be very precise; the same is true for quark masses. To prevent electrons from joining with protons immediately after starting, the lifetime of a neutron must have the value we observe: in the first few minutes, neutrons were formed, which were later incorporated into helium nuclei. Then, helium nuclei are particularly stable (remember that their binding energy is 24 MeV), so the helium did not

immediately turn into carbon and then into oxygen, allowing the stars to ignite gradually.

In other words, many different *constants* of physics had to have very precise values, to allow the universe to exist and evolve³³. Allan Guth, an American physicist, wrote in 1981 that the probability that these constants *would adjust themselves* is something like 10^{-50} , i.e. 1 after fifty zeros: in practice, totally impossible, unless there was another mechanism to adjust these constants. Thus was born the theory of *inflation*³⁴, even if this name is misleading, like that of the Big Bang, see fig. 3.21.

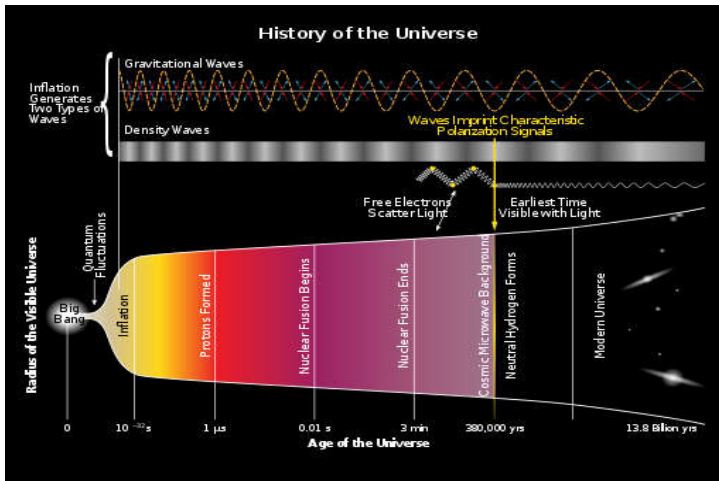


Figure 3.21. A representation of the history of the Universe, currently very popular. The initial explosion took place outside the laws of physics: we have no model either in cosmology or in elementary particle physics to describe the first instant of the Universe. After the separation of matter and light, i.e. at 380,000 years, the model of the Universe in expansion works well; the last "tube" section indicates that the expansion accelerates. Although the drawing is often reproduced, it remains deceptive: the time scale does not distinguish billionths of a second from billiards of a second. The initial bubble, the "quantum fluctuation", is a pure fantasy. SOURCE: Wikipedia Commons.

³³ Here we come to the question of the anthropic principle: are the constants of physics like this and then was the appearance of life and also our existence possible? Or are constants like this *to allow* us to exist?

³⁴ «These problems arise from the observation that to look like it does today, the Universe would have to have started from very finely tuned, or "special" initial conditions at the Big Bang. Inflation theory largely resolves these problems as well, thus making a universe like ours much more likely in the context of Big Bang theory.» FONTE: [https://en.wikipedia.org/wiki/Inflation_\(cosmology\)](https://en.wikipedia.org/wiki/Inflation_(cosmology))

Proponents³⁵ of the initial inflation of the Universe believe that the Universe exploded by a factor equivalent to something like 10^{26} in 10^{-32} seconds. A factor of 10^{26} means that the universe grew from the size of a pinhead³⁶ to a diameter 100 times larger than the size of our Galaxy (i.e. 130 thousand light-years). After that there was only a slow (by a factor of a thousand) swelling, up to the size of 13.78 *billion* light-years today.

There are no laws of physics (as we see it in the present, i.e. for 13.78 billion years) that can allow such inflation. Perhaps mere Physics did not exist at that time.

But absolutely more surprising is the other number: 10^{-32} seconds. The shortest time for the physical processes we know of is the jump of the electron from one orbit to another (i.e. the production of a quantum of light): 10^{-18} s. The Guth value corresponds to the shortest time we can imagine, close to "Planck time"³⁷ (10^{-43} s), which could be the minimum on the time axis. In other words: *the entire Universe appeared in the blink of an eye*.

Yet another problem arises: the explosion by a factor of 10^{26} in time of 10^{-32} seconds violates all the laws of physics, in particular Einstein's postulate (proven by all experiments) that the speed of light constitutes the maximum possible speed for the exchange of information (what is more limiting than the motion of matter). The speed of matter in the initial explosion should exceed the speed of light by a factor that is impossible to calculate.

It remains more reasonable to derive that the laws of physics were born *after* inflation, that is, that the initial explosion took place independently of space and time, or that space and time appeared "after the initial atom split in two", as Georges Lemaître was the first to intuit.

³⁵ «The detailed particle physics mechanism responsible for inflation is not known. The basic inflationary paradigm is accepted by most scientists, as a number of inflation model predictions have been confirmed by observations.» FONTE: Wikipedia, [https://en.wikipedia.org/wiki/Inflation_\(cosmology\)](https://en.wikipedia.org/wiki/Inflation_(cosmology)).

³⁶ An alternative calculation, made by a cosmologist friend, starts from the initial measurement of 10^{-17} m, which could correspond to the size of the quark, the smallest physical object imaginable. After inflation, the size of the universe would be a few meters, like the black and yellow spheres in the mosaic of the Basilica of Venice.

³⁷ The so-called Planck time does not derive from him and has no physical meaning: it is simply a game of physical constants organized in such a way as to produce the unit of measurement of time.

3.18. Size recalculation

The expansion of the Universe, which has lasted for 13 billion years, has swollen in size by a factor of a thousand. We have already seen that the hydrogen atom with an electron is practically empty. The cosmos is also an immense void. All the planets of the Solar System together weigh less than the Sun (about 1/5).

A friend, a professor of cosmology, wondering how much the universe has swelled in the "inflation" phase and what the dimensions have been after this phase, wrote the following equation: *unknown x unknown = unknown*. We just have to speculate.

From atomic physics we know that by crushing an atom, electrons are forced to join with protons (we still need an elusive anti-neutrino cell particle) into neutrons. Thus we go from dimensions of 10^{-10} m to 10^{-15} m. Matter composed of neutrons is consequently very heavy: a head "weighs" as much as a 10-storey building. And it is not differentiated at all.

The Sun reduced to a neutron star would have a diameter of about 14 km: 100,000 times less than its current diameter. The closest star to Earth, Proxima Centauri, is a little more than 4 light-years away, or 4×10^{14} km. Then there are other stars, but always a few light years away³⁸: the Universe is also essentially empty, even more than an atom. Thus, paradoxically, the entire universe reduced to a neutron star would be a little larger than our Sun.

In other words, on the first seconds, and up to 380 thousand years, we have no direct experimental evidence of the history of the universe. We can speculate on these early moments by extrapolating back the quark experiments. The mass (i.e. the equivalent energy) of the heaviest quark, *top* (172 GeV/c²) translated in terms of temperature (using the equivalence $E = kT$) corresponds to 2 trillion (2×10^{15}) centigrade. Does it make sense to talk about temperature? Can we apply the same laws of nature that we know to such extreme conditions? Were the same physics constants valid³⁹?

³⁸ For example, the star Pegasi-51, on which a first planetary system beyond the Sun was discovered, is 51 light-years away (Nobel Prize 2019!)

³⁹ An entire book by the famous Cambridge theoretical physicist, John Barrow, *The Numbers of the Universe*, was devoted to the discussion of the constants of physics. *The Constants of Nature and the Theory of Everything*, Oscar Saggi, 2004. It seems that the phys-

So, in summary, there is no doubt that the Universe began, in space and time. There is no doubt that the forms of matter ("earth" as *Genesis* says) were very, very strange. What? We don't know. There is also no doubt that the history of the universe, including the appearance of stars and the formation of the Earth understood as the entire planet, has been long and complicated. But at the same time, this evolution seems very "targeted", it means "teleological", using the language of Aristotle (and St. Thomas).

Almost, almost, the beginning of the Universe still belongs to philosophy rather than to physics.

Summing up cosmology and physics, it is difficult to call the first fraction of a microsecond (10^{-32} s) of the history of the Universe by any other name than creation *ex nihilo*.

This creation first established the laws of Nature: Nature, which in Galileo's words constitutes "the most observant executor of God's orders".

Then, in a certain sense, having established the laws of physics, the Universe went "on its own".

But this does not mean that God remained at rest...

P.S. There is a widespread opinion that many physicists, unlike certain other scientists, are believers. Because? Physicists know that the universe is governed by mathematical laws and understand that nothing happens by chance. They also know that the laws of physics are very complex (which is reflected in the complex structure of matter). Moreover, physicists are aware that they cannot explain *why* the world was made the way it was.

Socrates said⁴⁰:

Of course I am wiser than this man, even if, probably, both of us know nothing; only that he thinks he knows and knows nothing, while I, if I know nothing, am at least convinced of it, therefore, I know a little more about him, if only for the fact that what I do not know, I do not even think I know.

ics constants remain the same since the beginning of the Universe. Unfortunately, few conclusions are possible on the question: "Why is the world like this?".

⁴⁰ PLATONE, *Apologia di Socrate*, cap. 6, <https://it.wikiquote.org/wiki/Socrate>.

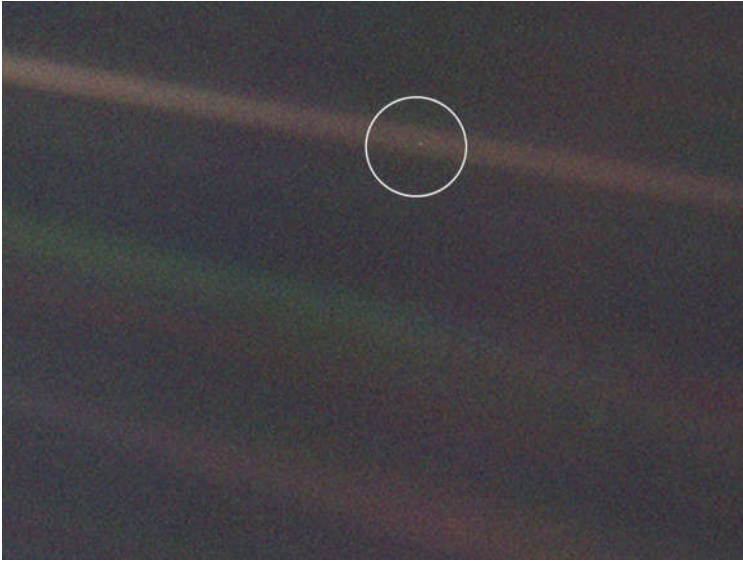


Figure 3.22. Bye-bye Earth! The last photo taken of planet Earth by the cosmic probe Voyager 1, at a distance of 6.4 billion km, before leaving the Solar System. Our entire planet is a blue dot, barely visible. But this grain of sand houses life, and then intelligent life. SOURCE: NASA.

God called the dry land 'earth'

4.1. "The Third Day"

The study of the cosmic microwave background, which is very cold (2.3 K, i.e. -270°C), reveals that the Universe is very old: 13.79 billion years. But when was the Earth born? We can deduce this from radioactive decays. As we have already said, heavy chemical elements, such as gold, uranium, platinum, can not be formed in normal stars, in which the chain of synthesis stops at iron and nickel. The star must collapse and the protons inside it must mix with the electrons under a very great gravitational pressure: this is how the whole variety of heavy chemical elements is born. Then matter explodes again, erupting into outer space.

From observations of supernova stars we know that an explosion occurs in few days and that the material formed in the contraction phase is scattered for billions of kilometers from the star. This was also the case with the star of the proto-Sun. But when?

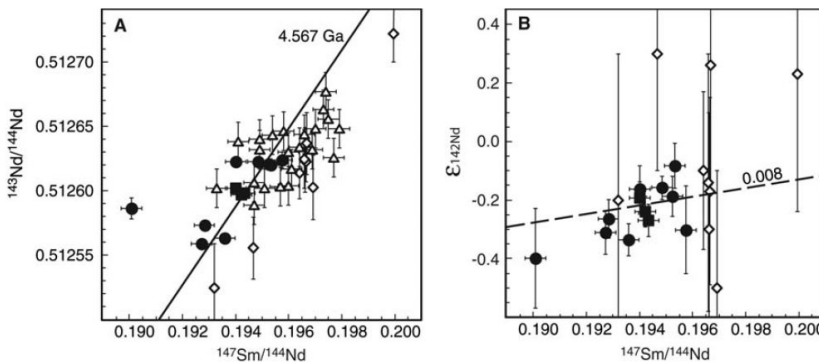


Figure 4.1. The study of the relative isotope contents of samarium ^{147}Sm and neodymium ^{144}Nd and ^{142}Nd , in basaltic rocks (black squares) and meteorites (other symbols): all data indicate the age of the Earth (and the Solar System) of about 4.567 billion years. SOURCE: M. BOYET, R.W. CARLSON, 'Science' 309 (2005), p. 576.

The radioactive decay of uranium ^{238}U is slow, with a half-life of 4.4 billion years. The end result of the long chain of reactions is lead. Thus, by studying the proportions of uranium and lead, we can deduce which portion of uranium has already decayed and, by comparing the half-life, we know how many billions of years have passed since the uranium was synthesized.

There are nuclei, such as samarium and neodymium, that allow even more precise dating. Countless studies are underway; one of them¹ gave the following number for the age of the Solar System (meaning also the Earth): 4.567 billion years.

Studies of radioactive isotopes (nuclei of atoms of different masses) make it possible to assess the age of the Solar System. According to recent data, the Sun (and the planets) formed about 4.567 billion years ago. This means that the Earth, understood as a planet (not as matter) appeared only at two thirds of the age of the Universe.

Such studies allow us to understand when the first rocks formed. The oldest are found in Greenland, Canada and Scandinavia. It seems that Canadian gneiss (i.e. very deformed granites) are 4.28 billion years old²: the first solidified "islands" on the still scorching Earth.

Several estimates indicate that the terrestrial globe was formed very rapidly (according to the cosmic time scale), i.e. in 10 million years. About 100 million years later, there was a terrible catastrophe: an object the size of Mars hit the still semi-liquid Earth, and an immense "drop" of lava was ejected into space. In 24 hours time the Moon was formed. They were the most horrible hours in the history of our planet: the entire globe could disintegrate. Even if Earth is still under a constant bombardment of meteorites, a cataclysm like that never happened later.

Comparing the age of the solar system with the age of the Universe, we come to the conclusion that two thirds have passed since the Beginning and only then our Sun lit up and the "earth" (using the spelling of the Bible), that is, the planet Earth, was formed. Was it really a "third" day?

¹ M. BOYET, R.W. CARLSON, *^{142}Nd Evidence for Early (>4.53 Ga) Global Differentiation of the Silicate Earth*, «Science» 309 (2005) p. 576.

² J. O'NEIL et al., *Neodymium-142 Evidence for Hadean Mafic Crust*, «Science» 321 (2008), p. 1828.

4.2. A small planet on the periferies

The Earth does not occupy a "central" position at all: it is the fourth planet of the Solar System (neither near nor far) and the Sun itself is located rather on the outskirts of our Galaxy (about 27 thousand light years from the center, compared to the radius of the Galaxy of about 87 thousand light-years).

The peripheral location has its advantages. At the center of the Galaxy is a gigantic black hole³, which sucks in matter and emits⁴ huge amounts of X-rays and gamma rays, which, as we already understand, are deadly for carbon-based life and delicate chemical compounds.

In 2012, the Voyager space probe, launched in 1977, went beyond the orbits of the last planets, at a distance 130 times greater than that between the Earth and the Sun. It was discovered that the entire Solar System is located inside an "egg" formed by the solar wind (see Fig. 4.2a). The solar wind repels a stream of highly energetic, i.e. dangerous, ionized particles that pervades the interstellar space.

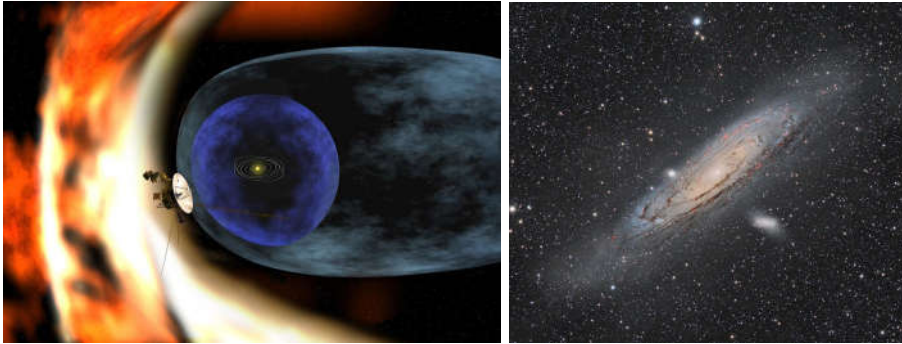


Fig. 4.2. In 2012, the Voyager-1 spacecraft arrived at what could be described as the "envelope" of the Solar System, a type of eggshell, the frontier between the delicate solar wind and the much more energetic flow of ions from inter-stellar space. This frontier is 130 times farther from us than Earth is from the Sun: it takes 20 hours for light to arrive from there. (b) Our Galaxy is most likely to be similar to the one visible to the naked eye in the constellation Andromeda. The Sun is located about 1/3 from the center of the Galaxy, that is, far from the regions characterized by strong radiation due to a possible gigantic black hole. SOURCE: NASA; D. WOS.

³ Only in 2019 did astronomers manage to photograph (with the radio-telescope system) the radiation emitted by a black hole at the center of our Galaxy.

⁴ Every electric charge (and the matter of stars is always ionized), if it is accelerated, emits electromagnetic radiation (for example X-rays). The only exception is electrons on the stationary orbits of the atom, according to Bohr's "postulates", see par. 3.7.

Much greater distances separate us from the nearest stars: 4 light years (i.e. 2 thousand times more than our solar "egg") from Proxima Centauri, 8 light-years from Sirius, 640 light-years from Betelgeza, a red giant that could explode in a few centuries from now. The hypothetical Oort cloud, the "parking lot" for a large number of comets that could hit Earth, is also at an appropriate distance (one light-year⁵). Thus, in today's times comet arrivals are rare events: as seen by the collision of comet Shoemaker-Levy with Jupiter in 1994, they are potentially very violent events.

Galaxies are also separated by large empty spaces: the Andromeda galaxy is located 2.5 million light-years from Earth. But we are getting closer: the collision will occur in 2 billion years. Although the integrity of our star should not be at risk, and only the constellation will vary, but possible consequences for delicate phenomena such as life could be fatal.

In recent years, thousands of planets have been discovered around distant stars. Perhaps even the majority of stars have their own plastic systems. But all the systems discovered so far (something like 5 thousand planets) are very different from the Solar System: they are composed either of gas giants like Jupiter, in most cases even very hot (a type of a quasi-star that did not ignite) or of rocky planets, but very close to their stars (for example a *Trapist-1* system). The Solar System, somewhat lonely in space, still seems unique.

4.3. Why do seasons exist?

The succession of seasons sometimes seems annoying: wouldn't it be better to have a single season with mild and sunny weather?

The seasons are due to the inclination of the Earth's axis: the angle of this inclination amounts to 23.5°. It is a fairly large angle: it means that between the position of the Sun at noon in winter (December 23rd) and in summer (June 22nd) the difference is 47°, that is, half of the right angle. So it is not only our impression that the winter sun (in Gdańsk, on the Baltic sea) just comes out little over the horizon, and in Sicily in July "hits" vertically.

⁵ The Oort zone could be at the edge of the cloud formed after the proto-Sun burst, like the "planetary nebulae", i.e. the remnants of supernovae.

The seasons allow not only people to take winter or summer holidays and vegetation to rest. Variable lighting throughout the year acts as a driving force for ocean currents and winds. The "Niño" oceanic current, which brings abundant fish along the coasts of Chile, is a seasonal phenomenon. Even Christopher Columbus knew that the trade winds blow westward in September and eastward in March.

But first of all, thanks to the tilt of the Earth's axis there are no "dead" zones on the Earth's globe. Where the sun is low (above the Arctic Circle), it shines on the sky for half the year: it is the polar "day". In Alaska during the polar day, the temperature reaches 30°C, more than in Seattle, which is located southeasterly.

Then, winter is also needed: white bears wait for the cold season, when the ice cap extends to the continent, to hunt seals in their "ventilation windows". A problem emerges recently, with a slow but steady warming of the climate causing the ice pack to recede. But the longer summer causes seals to proliferate. And when bears in the Arctic begin to fast, penguins brood in Antarctica. Thus, the biological life on Earth does not stop anywhere. And trees, resting in winter, live longer.

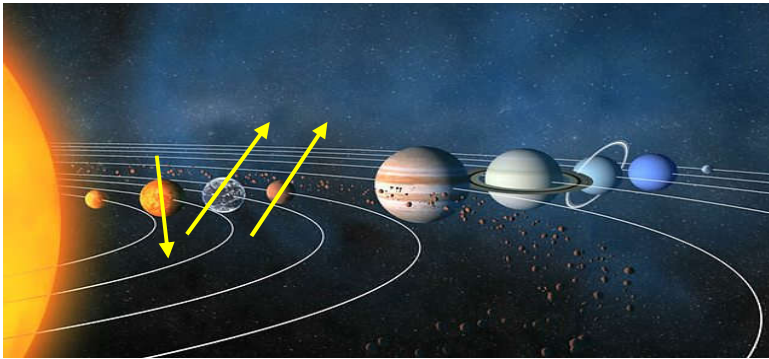


Figure 4.3. The Solar System: Four relatively small planets composed of heavy and solid matter are located in the inner part (the radius of the orbit of Mars is 1.5 times that of the Earth). The outer planets, which are much larger, revolve at distances 5 (Jupiter) to 30 times (Neptune) farther from Earth. All these four outer planets, but in particular Jupiter, play the role of "safeguarding" the inner planets against the bombardment of meteorites. All planets rotate on themselves: Jupiter and Saturn in about 10 hours; Mars and Earth in about 24 hours, Venus once in 9 months (and in the opposite direction). SOURCE: Wordpress file editing <https://tragicocomedia.files.wordpress.com/2015/11/solar-system.jpg>.

The cause of the seasons is the inclination of the Earth's axis, but it would not be enough on its own for the development of life on the planet: it is necessary for this axis to be stable over a long period, hundreds of millions of years. A similar tilt of the axis is observed in the case of Mars. But unlike Earth, Mars does not have a magnetic atmosphere and field; the Moon is also missing. It turns out that our companion, the only natural satellite, the Moon, plays an important role in stabilizing the motions of the Earth.

4.4. A satellite, i.e. a companion

Our globe is a particular planet throughout the Solar System also because of its Moon, about a quarter the size (i.e. diameter) of the Earth. The mass of the Moon is 1/81 of the mass of the Earth and the distance of one from the other is relatively short: about 10 Earth circumferences (varies during the year from 364 to 404 thousand⁶ km). In the case of stars, such a pair would be called a binary system. In fact, the motions of the Earth and the Moon are correlated: the Moon rotates on itself but with a period equal to the time of revolution around the Earth (28.9 days⁷). Indeed, more precisely, it is not the Moon that revolves around the Earth, but both revolve around the common barycenter, which is located at a depth of about 1700 km (with respect to the radius of the Earth of 6378 km).

In 1993, three French mathematicians demonstrated⁸ that the Moon plays a stabilizing role for the Earth. Without the Moon, the Earth axis would have undergone strong oscillations, up to differences of 30° in a few million years, with serious consequences for the stability of the climate, what would have prevented the development of life. The role of the Moon can be compared to a rod, light but long, which the tight-rope walker holds so as not to fall, see fig. 4.4b.

⁶ Another similar system is Pluto with its largest satellite, Charon. The period of Charon and Pluto's own rotation is equal to their period of mutual revolution. But Pluto is smaller than Earth.

⁷ We are talking about the synodic month, that is, the rotation around the Earth in the reference system of the Earth (which in turn revolves around the Sun). The rotation period in the fixed star reference frame is 27.3 days (one sidereal month).

⁸ J. LASKAR, F. JOUTEL, PH. ROBUTEL, "*Stabilization of the Earth's obliquity by the Moon*", «Nature» 361 (1993), p. 615.

The axis of Mars is tilted in a similar way (25°) to the Earth axis, but in the absence of the heavy moon (Mars has only two small satellites) the inclination is subject to strong variations (from 10° to 60°) over long periods. As the prestigious scientific journal 'Science' comments⁹, these oscillations caused strong climate changes and contributed to the loss of most of the planet's atmosphere, leaving Mars "in the state of a dry desert to the last bone", as it appears today.

The Moon still exerts a function: it creates the tides. The tides in London (since the variation of the Thames level exceeds 5 meters) allow to discharge the ship (even if only in 6 hours) on dry land and immediately afterwards launch the ship, without moving it. The influence of the tides on animal life can be seen on the sea beaches: as soon as the water recedes, the crabs quickly arrive to find something to eat. In the past, when the Moon was closer¹⁰, the tides must have been really gigantic. The fish that remained dry had to develop alternative respiration to gills: amphibia were born.



Figure 4.4. (a) The photo taken on the Moon by the Apollo astronauts seems to show that the Earth rises above the horizon; in reality, the Earth seen from a certain point on the Moon always remains in the same position, like a lamp, but turns quickly (one lap in 23h56m) and presents the phases, like the Moon seen from Earth. (b) The Moon acts as a counterweight to the Earth. (c) The other side of the Moon, invisible from Earth: it was subjected to a heavy bombardment of meteorites, thus protecting the Earth from these catastrophic impacts. SOURCE: NASA; GK; Wikipedia.

⁹ «That caused huge climate variations that in turn could have contributed to the loss of most of the planet's atmosphere, leaving Mars the bone-dry desert world that it is now. Since then, most astrobiologists have assumed that Earth-like planets in other solar systems would need a comparatively large moon to support complex life over long periods of time.» <http://www.sciencemag.org/news/2011/05/who-needs-moon>.

¹⁰ Apollo astronauts placed mirrors on the Moon. Sending laser beams from Earth it was discovered that the Moon is moving away, by about 3 centimeters per year. In a few million years there will be no more beautiful total eclipses.

The presence of the Moon seems necessary for the existence of life, since it seems that it is present in no more than 1% of extraterrestrial planets. Govert Schilling in his aforementioned "flash" of 'Science' "Who needs the Moon?" continues: "This would mean that the planets that host complex life can be relatively few".¹¹

When man, live on television from Apollo 8, saw the Earth above the horizon of the Moon for the first time, he was seized by a mixture of respect, anxiety and wonder¹². The astronauts, flying towards our globe, took turns reading the fragments of *Genesis*.

4.5. Bacon: Easter too early

The Earth rotates like an inclined gyroscope. But an inclined spinning top "rocks", that is, it makes slow turns around the vertical axis. The Earth too, but being much larger, these turns are very slow (one every 25 thousand years). The name of this phenomenon, also known by Copernicus, is precession. Indeed, precession was the cause of the reform of the calendar wanted by the Catholic Church at the time of Copernicus (and introduced in 1583 by Pope Gregory VIII). Why?

The Christmas, lacking precise dates, was set at the winter solstice. For the Resurrection there are irrefutable documentation, such as the Holy Shroud¹³: the Resurrection coincides with the Jewish Passover. But it is a moveable feast: it falls on the Sunday after the first full moon of spring. Then the beginning of spring must be determined. It would not be difficult to use the stars as a reference, choosing when the Sun "enters" the zodiacal constellation of Aries. And so it was fixed for more than a thousand years, since the reform of the calendar approved by Julius Caesar. But from a practical point of view, especially in agriculture, it would be better to organize oneself according

¹¹ "That would mean that planets harboring complex life might be relatively rare." FONTE: <http://www.sciencemag.org/news/2011/05/who-needs-moon>.

¹² «Said Lovell, 'The vast loneliness is awe-inspiring and it makes you realize just what you have back there on Earth.' They ended the broadcast with the crew taking turns reading from the book of Genesis.» FONTE: NASA https://www.nasa.gov/multimedia/imagegallery/image_feature_1249.html.

¹³ We indicate, for example, the extraordinary book by PIERLUIGI BAIMA BOLLONE: 2015. *The New Investigation on the Shroud. Two thousand years of history and the latest scientific evidence*, Priuli & Verlucca, Ivrea 2015.

to the seasons, choosing the day of the equinox as a reference. The Neolithic calendar of Stonehenge already worked like this: the megaliths are placed in such a way as to indicate the summer solstice. But the Julian calendar, with the passing of the centuries, slowly began to diverge. The problem became acute in the Middle Ages.

The Middle Ages, contrary to widespread opinion, was a season of great technological progress: the plough, the mills, the rotation in agriculture, the buttons - are all medieval inventions. It also produced great results in the sciences: John Buridan (ca. 1300-1360) discovered the principle of inertia, which today coincides with Newton's first law of mechanics. Vitellius (ca. 1237-1300), a priest of Polish (and Thuringia) origin, reorganized optics, introducing the law of reflection, built the periscope, described the anatomy of the eye and meditated on visual perception¹⁴.

Roger Bacon (ca. 1214-1292) in *Opus Maius* reorganized knowledge from astronomy to physics, from mathematics to linguistics and geography. Discussing the calendar, he complained of a serious conflict: in the Julian calendar, every century the day of the equinox moved towards February.

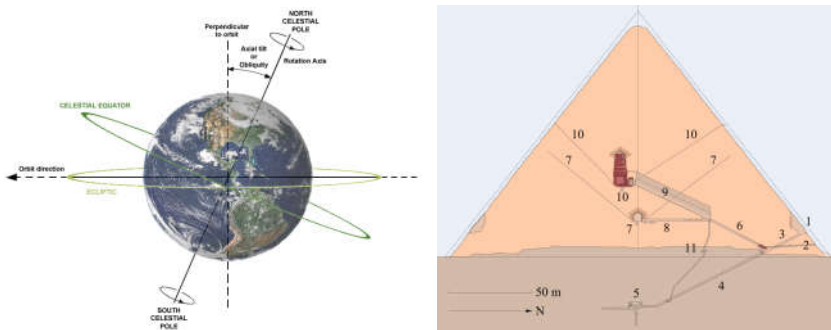


Figure 4.5. (a) The three motions of the terrestrial globe: beyond the proper rotation and the revolution around the Sun, the north pole of the earth's axis completes a complete revolution in 25 thousand years. This motion, called precession, was also known to Copernicus: the need to explain it was one of the reasons that prompted him to write his treatise. (b) The section of the pyramid of Cheops: one of the "aeration" channels could point towards the polar star, which was Thuban in the year 2500 BC. Today the North Star is something else entirely: the *alpha* of Ursa Minor. SOURCE: Wikipedia, DENIS NILLSON; «Nature», 2017/11/02.

¹⁴ On three-dimensional perception, Vitellio wrote: "When we look at an object, we never see it in its total spatial extension; it will be the soul's judging function that tells us that we see the object and not its image." Witelo, *De Perspectiva*, University Toruń Press, 2004.

This shift was a serious problem for Bacon. During Lent one can not eat meat, while during carnival (=meat value) one can: the risk was to make the end of carnival overlap with the beginning of Lent. It would be a serious, “diabolic” problem, said Bacon!

The "movement" of the equinox around February was called the "pre-cession". Today this term belongs to physics: it is the slow motion of the Earth's axis, similar to an inclined spinning top. We also observe the precession as a slow shift of the North Star. Today it is the *alpha* of the Ursa Minor, but it was not so five thousand years ago when the pyramid of Cheops was built. One of the channels leading from the king's chamber in this pyramid points to a star, but it is not today's North Star: five thousand years ago the axis of the Earth's rotation pointed towards the star Thuban in the constellation of Draco.

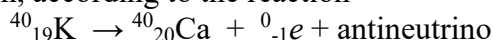
Copernicus was one of the experts called by the Pope to resolve the issue of precession. In fact, already in the first pages of his work he wrote that the Earth makes three types of motion. Thus, the Copernican revolution was born in part from an ecclesial necessity.

4.6. Why do earthquakes happen?

Earthquakes are among the most frightening disasters. The populations of the past knew this, so the east coast of the Apennines (i.e. Umbria) is not very urbanized compared to the west coast (Rome, Naples), despite the fact that the latter was (and still is) volcanic.

Geologists answer that earthquakes occur due to the movement of continental plates. The Apennine peninsula detached itself 20 million years ago from the African coast and turning counterclockwise hit the European continent: the clash zone is the Alps.

But why four billion years after its formation has the earth's crust (very thin, barely 20 to 60 kilometers) not yet solidified? Nuclear physics answers. The earth's crust contains metals that form oxides, including both heavy uranium and light potassium, a component of clays (and of our organisms). Both uranium and potassium are radioactive. In different ways: uranium splits in the reaction (3.4) from the previous chapter. Potassium is transformed into calcium, emitting an electron, according to the reaction



Both uranium and potassium are *weakly* radioactive. Weakly means that in a unit of time a few nuclei split; few means that the reaction is slow and lasts a long time. For potassium ^{40}K the "half-life"¹⁵ is 1.2 billion years; for uranium ^{238}U it is even longer - 4.4 billion years, a time comparable to the age of the Earth. In other words, half of the uranium that formed in the proto-Sun still remains on Earth.

Here we come to the conclusion: the earth's crust is constantly moving, because it is heated from below. An exact balance, obtained in 2011 through the measurements of the neutrino flux resulting from the reaction (3.4). It turns out that half of the heat flow comes from the center of the Earth, which is still very hot (over 5 thousand degrees); for the other half the decays of uranium and potassium contribute about equal parts.

Earthquakes are horrible disasters, caused by the movement of continental plates, which collide continuously and one of them emerges (as the Himalayan range), while another sinks. But, as it sinks, the plate melts (hence the volcanoes, for example of Japan or of the Andes chain). This causes limestone deposits to melt, releasing CO_2 into the atmosphere. And this ensures the greenhouse effect, positive for the biological life, which we will talk about later.



Figure 4.6. (a) The flow of heat from the interior of the Earth creates convection currents, which cause volcanoes to erupt and continents to erupt, as in this "lava" lamp. (b) The section of the Earth resembles an avocado: about half is made up of the iron core, liquid on the surface and solid inside; the next layer called the mantle is semi-liquid, like the flesh of the avocado; only the superficial layer, very thin (10 km thick under oceans, 70 km in Scandinavia) is solid: mountains on earth are like the rough rind of avocados. (c) Earthquakes occur when the displacement of the continental plates is not uniform. Here is the situation in Japan: a thin Pacific plate slides under the thick Asian plate. On the "windowsill" appear volcanic islands and on the "suture" - the earthquakes succeed. SOURCE: GK.

¹⁵ Half-life is the period during which half of the radioactive substance splits (or is subjected to another type of reaction).

4.7. Why is there no life on Mars?

Mars (and also Venus) are planets very similar to Earth: about the same distance from the Sun (Mars 50% farther, Venus 25% closer) and only a little smaller. But the average temperature on Mars is -40°C and on Venus $+400^{\circ}\text{C}$. Where do these differences come from? By factors, it would seem, of little importance, such as the components of the atmosphere.

In the primordial atmosphere on Earth there was no oxygen, which was bound in chemical compounds with metals (i.e. oxides) and the remaining part formed CO_2 and SO_2 . Water was also in the form of steam. In addition, the atmosphere was rich in methane (CH_4), ammonia (NH_3), hydrogen sulfide (H_2S), hydrogen cyanide (HCN). An accentuated electrical activity in the atmosphere (lightning) must also have formed nitrogen oxides (i.e. nitric acid). As a result, the soil was rich in nitrogen salts, and plants developed the nutrient system that absorbs nitrogen from the soil and carbon dioxide from the atmosphere.

Today, the proportions are completely different: nitrogen in the atmosphere is found in its molecular form N_2 ; only traces of CO_2 in the gaseous form remain. Huge amounts of CO_2 have been "buried" within the Earth's crust. One part was reduced to pure carbon (extracted today in mines), another part formed several hydrocarbons (oil, natural gas) and the rest was deposited as calcium carbonate (limestone, marble). But the sequestration of CO_2 from the atmosphere is all the work of life that appeared on Earth about 3.5 billion years ago.

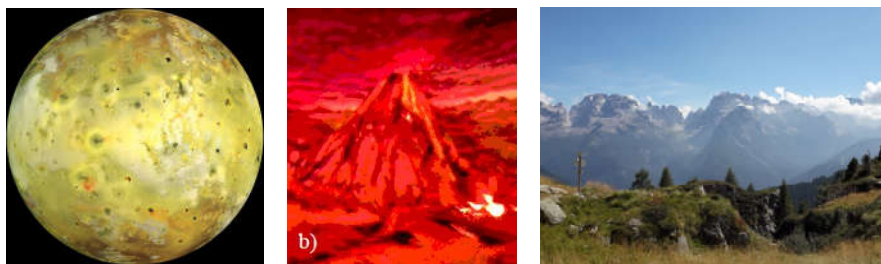


Figure 4.7. Earth has had a long history of hosting life on land (still, i.e., "dry"). (a) The primordial atmosphere was opaque, yellow-purplish, like the surface of Io, one of Jupiter's (Galileo) satellites: its atmosphere contains sulfur dioxide (SO_2). (b) An artistic view of the primordial earth ("Geodium", Toruń, concept GK). (c) This is biological life (and man) that makes the earth so beautiful: Brenta Dolomites. SOURCE: (a) NASA/Photojournal/PIA02308; (b, c) MARIA KARWASZ.

Life on land appeared about half a billion years ago: only when enough oxygen formed in the atmosphere for plants (and animals) to breathe. The presence of oxygen in the atmosphere (today about 21%) is also the work of life.

On Mars, the atmosphere is very rarefied: oxygen is bound in iron oxides (which give its surface the red color), but first of all there is no water in the atmosphere as it is too cold. But it is cold because there is no water vapor in the atmosphere. It seems a paradox, but in electronics it is called a "feedback".

The temperature on earth calculated on the basis of the amount of energy that derives from the Sun should be on average -18°C , and instead amounts to $+15^{\circ}\text{C}$. The difference of $+33\text{K}$ is due to the particular composition of the atmosphere that contains both CO_2 and H_2O . The main gases of the atmosphere, N_2 and O_2 , are simple and symmetrical molecules (unlike for example NO , which is asymmetric). Asymmetric molecules, such as H_2O , have the electrical charges (positive and negative) displaced: thus they absorb electromagnetic radiation, particularly in the infrared (more on this later).

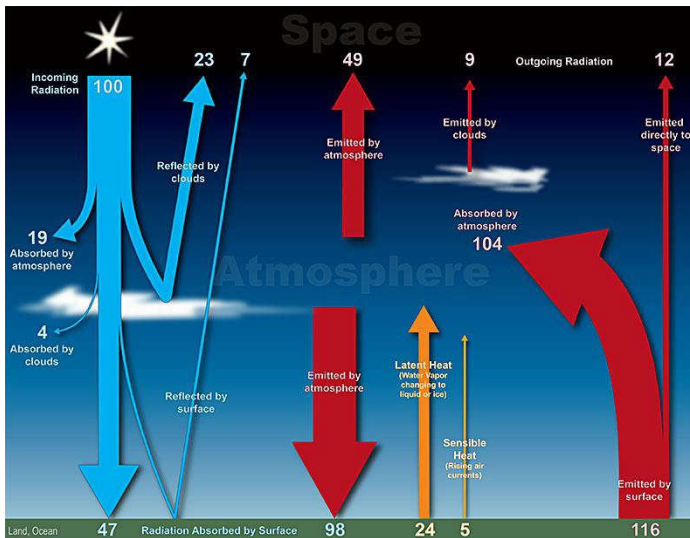


Figure 4.8. The energy balance on Earth is very complex. 50% of the incoming solar radiation is visible light, while the Earth emits infrared radiation. Clouds reflect the sun's rays but the greenhouse gases CO_2 , H_2O absorb infrared radiation and send it back to Earth. Thus the total amount of energy available at the ground level amounts to 116% of the energy coming from the Sun. SOURCE: NOAA (USA) https://www.weather.gov/images/jetstream/atmos/energy_balance.jpg.

The Earth's atmosphere today (2024) contains¹⁶ 412 parts per million of CO₂: it seems little, but it is just enough to cause, together with water vapor, the intrinsic increase in temperature of +33 K. Two two molecules, H₂O and CO₂ absorb infrared radiation, indeed they are complementary: CO₂ closes the absorption "window" that remains open in the H₂O spectrum.

But should not the absorption of radiation lead to a decrease in temperature? Yes, but one detail must be specified. The radiation that comes from the Sun is mainly visible light, which has a characteristic temperature of 5700 K. The Earth's temperature on average is 288 K (+15°) which corresponds to the infrared. Therefore, the presence of CO₂ does not prevent solar radiation from reaching the surface of the Earth, but it prevents the escape of infrared radiation (i.e. heat) towards the cosmos. Infrared returns to Earth: it is a ping-pong effect. Thus, paradoxically, the Earth has more energy at its disposal than that which comes from the Sun: 116% of it (fig. 4.8).

CO₂ and H₂O are two gases responsible for this natural "greenhouse" effect, thanks to which life on Earth flourishes. There is CO₂ in the atmosphere of Mars, but there is no water vapor (because it is too cold). So the infrared radiation is not trapped: the "greenhouse" effect is just +3K. On Venus the opposite happens: many CO₂, SO₂ and H₂O cause the greenhouse effect of something like +350 K. Neither on Mars nor on Venus (today) does life exist. There are still other reasons, but more on that later.

4.8. An iron heart

Mercury, Mars, Venus belong to the same class of planets as Earth: telluric, that is, made of a rocky matter. The composition of the surface of the Moon (from where stones were brought) and Mars (where the analyses are carried out by autonomous robots) is not very different from that of volcanic rocks on Earth. On Mars there is even iron in abundance. But the difference is that Earth is the only one of these four planets to have a magnetic field.

¹⁶ As late as the year 1900, the atmosphere contained only 270 ppm of CO₂. This increase is due to human action, burning carbon resources buried over billions of years in the form of coal and hydrocarbons.

The nucleus in the atom is extremely small; the Earth's "core" extends to about half its radius¹⁷: it should be called the core, since it is hard (and heavy). If the typical density of granite (of which Scandinavia is made, for example) is 2.7 g/cm^3 , the average density calculated for the whole globe is 5.5 g/cm^3 (the density of iron under normal pressure is 7.8 g/cm^3): it is therefore understood that the core must be made of a heavy material.

We do not know the exact composition of the Earth's core: it must be made of iron, but of a compact (and heavy) metallurgical phase. In the core there is almost certainly also nickel: both iron and nickel are magnetic. It is the iron in the Earth's core that creates the magnetic field, which is also essential for life on Earth.

The Sun, in addition to the pleasant heat (40% of the spectrum is infrared radiation) and light, also emits electrically charged and very energetic particles, which arise from atomic processes on its surface. The flux of these particles is considerable and could damage biological structures, especially DNA.

Life has "incorporated" the magnetic field into its regulation processes: Swedish nightingales wait for a slight change in the magnetic field to change their plumage (and leave southwards) in September.

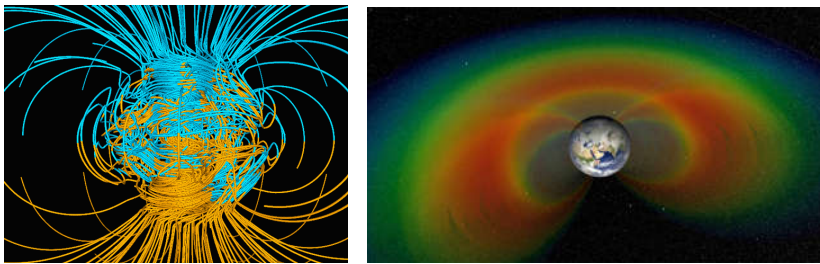


Figure 4.9. (a) The Earth's magnetic dynamo model: the complex structure of the field on the Earth's surface is due to a "tangle" of lines within the hot, rotating iron core (with the whole globe). (b) The magnetic field protects us from the flow of energetic particles from the Sun (solar wind), which are harmful to life. The particles are conveyed towards the poles, where they give the spectacle of the aurora. SOURCE: NASA, GARY A. GLATZMAIER; NASA/Goddard Space Flight Center/Scientific Visualization Studio.

¹⁷ The so-called Gutenberg discontinuity, obtained from the propagation of seismic waves across the globe, is located at a depth of 2900 km and marks a rapid change in the density of the material, from 10 g/cm^3 (denser than iron under normal pressure) to 13.5 g/cm^3 . The average radius of the Earth is 6379 km; the iron core extends to about half the radius.

Florida turtles use the magnetic field to lay their eggs on the same beaches where they were born¹⁸. Surely even pigeons, flying, build a magnetic map. Maybe even that man had (still has?) this ability.

4.9. The Planet is self-regulating

We discussed how today's Earth's atmosphere was formed in the long process of adapting to living conditions. We also explained that the beneficial greenhouse effect, essential for life, is minimal on Mars and too intense on Venus. But speaking of the favorable climate for life on Earth, the "feedback" announced earlier must be discussed in detail.

Feedbacks are self-regulating mechanisms, but they can lead to both stabilization and catastrophe. By adjusting the volume of the TV set we use an amplifier inside the instrument, which increases the amplitude of the signal carried by the electromagnetic waves up to a desired level. But an acoustic amplifier can also go "haywire", when the microphone is placed close to the speaker: instead of the amplified signal, a painful whistle is heard and a destabilizing feedback (a positive one) has been created.

There are also two types of feedback in climate processes. The presence of water vapor in the atmosphere is a typical example of positive feedback, i.e. with a destabilizing action. In section 4.8 we specified the CO₂ content in the atmosphere but not H₂O. In fact, the latter is subject to feedback.

The water vapor content in the air depends on the temperature, we all know that. In Siberia, in winter, the air rejected by the lungs becomes fog, or even takes the form of ice crystals. On the other hand, in the Finnish sauna you can lose consciousness, because there is only water vapor (100%) in the air and there is no oxygen.

The content of water vapor varies greatly with temperature: the higher the temperature, the larger its content. And since H₂O in the atmosphere is a gas that contributes to the greenhouse effect, we have a positive feedback: the temperature increases and consequently the H₂O content increases, the greenhouse effect and therefore further the temperature itself. This mechanism happened in the atmosphere of

¹⁸ G. KARWASZ, *Magnetic turtles*, in: On the Track of Modern Physics, dydaktyka.fizyka.umk.pl/Physics_is_fun/html/turtle.html.

Venus (in conjunction with the presence of other greenhouse gases, such as CO_2 and SO_2).

The temperature on Earth depends on several other factors, including the amount of reflected solar radiation, called *albedo*. It depends on the type of vegetation on earth: the steppe reflects more than the jungle; the highest albedo is due to snow. And here comes another positive feedback: with the drop in the average temperature on the globe, more and more of its surface is covered by snow. Consequently, the higher the average albedo, the greater the reflected solar energy and the lower the average temperature.

In other words, several factors make the climate on Earth unstable. In the last 500 thousand years, glacial periods have become intertwined with interglacial ones. And in ancient history (1-2 billion years ago) there were periods when most of the globe was covered by ice: traces of glacial erosion can be found on the rocks of the continents that were at the equator. But the ice cover should have caused the extinction of life. Yes, but it also accelerated evolution: life proliferated around volcanoes and evolution could have tried several alternative solutions, out of which, after the melting of the ices, the best won.



Figure 4.10. (a) In the period of the global glaciations, there was already oxygen in the atmosphere-sphere: so the aurora borealis, which are due to O_2 and NO (Geodium, Toruń), could also be observed. And perhaps the presence of oxygen caused large temperature fluctuations on the global scale. (b) Hydrothermal vents are environments rich in surprising life, in which energy is not obtained from the Sun, but from chemical reactions. (c) The desolate landscape of Mars, devoid of water and limestone rocks. In June 2018, it seems, that traces of substances deriving from the decomposition of organic molecules were found: it cannot be excluded that in ancient times (a couple of billion years ago) some primitive form of life existed on Mars. SOURCE: Geodium, Toruń (GK); NASA Astrobiology Institute; <http://mars.nasa.gov>.

At the moment the theory is not yet fully proven.

Returning to feedback, vegetation, and life in general, plays a stabilizing role: it increases the CO₂ content and consequently, in a chain, temperature and humidity; moreover, the conditions for vegetation improve and therefore the CO₂ sequestration by plants increases: the CO₂ content decreases.

Sometimes the self-regulating mechanisms of planet Earth are *personified*, under the name Gaia. The concept was coined in the 70s of the last century by an American astrophysicist, James Lovelock, who, commissioned by NASA to verify whether life could exist on Mars, answered negatively. The sign of life is the presence of oxygen: from space the planet appears blue. But there is a bit of a difference between natural processes, governed by external laws, and intelligent life: "Gaia" is only an organism (inanimate), that is, an organized *thing*, not the *organizer*.

To sum up: the present arrangement of the Earth is largely due to the appearance and proliferation of life on it. Man has a great influence on his planet (and also a great responsibility). Perhaps the first to understand this was St. Francis.

4.10. An Earth for Man¹⁹

With the discovery of so many planetary systems (the Kepler satellite has found as many as seven planets around the star Trapist-1), the question of whether Earth is a special planet has come back to life. From the point of view of the anthropic principle, the answer would be obvious: yes, because intelligent life exists on Earth and we have so far no archaeological or astronomical evidence that it exists elsewhere in the Universe (palpable, i.e. observable by means of physics). The Catholic Church, in the words of Professor George V. Coyne, astronomer from Arizona and director of the Vatican Observatory, does not rule out such an existence but does not even prove it²⁰.

"Father, do you believe in other inhabited worlds?"

¹⁹ I use the title of a popular exhibition of the "Mosaico" association that took place at the Rimini Meeting in 2002.

²⁰ V. MESSORI, *Inquiry into Christianity. Forty-seven voices on the mystery of faith*. Oscar Mondadori, 2003 (first edition 1993), p. 168.

If we look at statistics, it is certain that the conditions for life must have been fulfilled: and not in a single point of the universe. There are hundreds of billions of stars like the Sun, inside and outside our galaxy, and it is certain that a large part of them have a system of planets like the Sun's. Even if we are pessimistic and exclude most of these planets, we still arrive at a very high number of celestial bodies where the same conditions as on Earth must have occurred. But be careful, I'm talking about *conditions*. I am not saying that life has actually developed from these favorable conditions. Only this can be said by the scientist.

- And what does the man, the religious Father Coyne think?

"Personally, discovering that our Earth is less, much less than a grain of sand on an immense beach, I wonder why God would have created this enormous stage that is the universe only for us. But do we have the right to ask ourselves this? We are not God, we cannot know his thoughts. The law of creation seems to be something that seems to us to be a gigantic waste: billions of spermatozoa thrown away, for example, so that only one – and certainly not always – provides for reproduction. The same waste, at least apparent, can be seen by scanning the skies. As a private person I would say yes, there is life elsewhere too. But I have no certainty. For the believer, life is not born by chance, by the laws of statistics, by a fortuitous physicochemical combination: evolution is born by a divine *fiat* and follows the program of a Creator.

Without a doubt, cosmology, astronomy, geology and physics contribute to recognizing a particular character of the Earth: a rocky planet, with a chemically inert atmosphere (apart from the oxygen whose presence is due to life) and with large quantities of water, at the "right" distance from the Sun to ensure an adequate flow of electromagnetic energy. On the other hand, the presence of uranium and thorium, elements that must be formed in supernovae, ensures the movements of the plates and consequently a delicate balance in the CO₂ atmosphere, which is a "fodder" gas for plants.

Other heavy chemical elements (selenium, copper, bromine, iodine) also do not exist in first-generation stars. Also essential for life is the enormous amount of iron, the condition for the self-generation of the magnetic field in the heart of the Earth.

The presence of the Moon, large and close, ensures not only the "nocturnal illumination", but first and foremost the stability of the climate. It cannot be ruled out that the inclination of the Earth's axis, which determines the very complicated dynamics of ocean and atmospheric currents, is also the result of the collision that formed the Moon.

To sum up, thanks to a series of particular "coincidences", between cosmology, astronomy, geology, climatology, the Earth hosts life. And it is not just a matter of mere "coincidences", but of a whole temporal sequence of events: the explosion of the proto-Sun, the formation of the Earth, its slow cooling, the formation of the oceans, the production of oxygen, the first animals on land, etc.

We do not know if life was born on Earth or if it comes from the cosmos. In all probability (a scientist should never talk about the impossibility) the Earth remains the only place where there is life in the entire Universe.

4.11. Life beyond Earth?

Since 1992, i.e. since the discovery of a first planetary system around a neutron star (by an astronomer from Toruń who worked in the USA, Aleksander Wolszczan) several methods have been developed to detect the presence of cold bodies (precisely: planets) in space. Radio telescopes, optical telescopes and even specially built satellites (e.g. "Kepler") are used. Today (December 26th, 2024) we know almost six thousand planets (exactly²¹ 5811).



Figure 4.11. Rocks, water, snow, magnetic field, oxygen: all the essential elements for life are visible on this photo used as a screensaver by Microsoft Windows 10 on 31/12/2017.

²¹ <https://en.wikipedia.org/wiki/Exoplanet> (accessed 26/12/2024).

Most of these planets belong to the category of cold gas giants, such as Jupiter and Saturn. Recently, small, heavy, probably rocky planets have also been discovered, perhaps with atmospheres. Some may contain water, in much larger quantities than all the oceans on Earth. We're looking to see if any planet has a gaseous atmosphere with, perhaps with oxygen. In total, in the entire Universe, there will be a billion planets, if not more.

Does life exist on these planets? We don't even know if the conditions on them really allow life. The star of the Trappist-1 system, studied recently, is a cool red dwarf (i.e. a fairly old star, in the advanced stage of its evolution), 40 light-years away. The periods of revolution of seven planets around it (i.e. the length of their year) are from 2 to 19 days. As Natalie Batalha, the researcher of the Kepler mission, expressed it, we do not know if the Trappist-1 planets can host life: "You don't count chicks before the eggs hatched".²²

Earth remains a special planet for life. The proof? Life itself, made up of the chemical elements found on our planet.

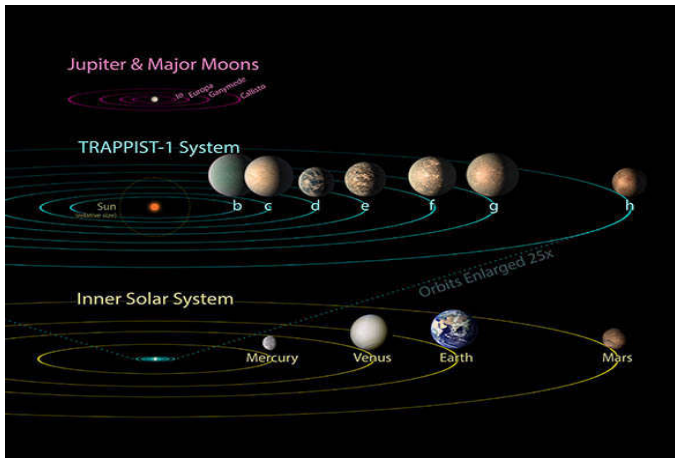


Figure 4.12. The seven planets of the Trappist system around a red dwarf. Despite an apparent analogy with the Solar System, the planets are more like Jupiter and its moons: with periods of revolution of a few days and the distances from the star are less than that of Mercury from the Sun. SOURCE: NASA/JPL-Caltech.

²² «They say not to count our chickens before they're hatched, but that's exactly what these results allow us to do based on probabilities that each egg (candidate) will hatch into a chick (bona fide planet).» <https://www.outerplaces.com/science/item/16234-kepler-nasa-exo-planets-life>.

A multitude of living beings

"Let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth in the open firmament of heaven." ¹

- God said (but only on the fifth day).

5.1. From inorganic to organic

Physics is mainly concerned with the inorganic world: balls, atoms, elementary particles. But the laws of physics (for example, that the electron has *spin* $\frac{1}{2}$) also determine chemistry, i.e. the variability of chemical compounds. Already discussing diamond and graphite crystals we understood that carbon is a particular chemical element – it has few (6 in total) electrons, of which 4 are chemically active. Thus a carbon atom can give up to 4 electrons (a simplified model is the molecule of $\text{O}=\text{C}=\text{O}$) or accept up to 4 electrons (in CH_4). Carbon atoms can also form chains (as in acetylene $\text{H}-\text{C}=\text{C}-\text{H}$). These properties make the chemistry of carbon compounds infinitely richer than any other element. So the first determinant for passing from the inanimate world to life is the richness of possible organic compounds. However, from organic chemistry to biology, the road is still unknown.

The essential feature that differentiates chemistry from biology is the fact that in chemistry the reactions, which are in practice the exchange of electrons between two atoms, take place in a simple contact with each other: hydrogen explodes if mixed in the right proportion with oxygen. But even in chemistry there are certain reactions that continue in the presence of *catalysts* – such as vanadium (for the production of sulfuric acid), iron oxides (for the production of ammonia)

¹ *Genesis*, 1, 20, *St. James Bible Pure Cambridge Edition*, <https://archive.org/details/king-james-bible-pure-cambridge-edition-pdf> (29/12/2024)

etc. In the catalytic converter, the oxidation of CO to CO₂ and the "re-reduction" of NO_x to N₂ take place: cerium oxide (CeO₂) and colloidal platinum are used. The function of catalysts in the reaction process is to ensure the "loan" of electrons to the reacting atoms (molecules).

In biology, practically all reactions take place in a catalytic, or rather *enzymatic*, way. Enzymes are like catalysts: they attach electrons to the reactants, but in a very specific order and place. But between chemical catalysts and enzymes there is an essential difference in complexity.

5.2. From simple to complex: a thermodynamic pathway?

In physics and chemistry, reactions usually go in the direction of the minimum energy: a ball rolls down the slope, because its energy ("potential") at the bottom of the slope is lower². In chemistry, coal burns, because the total energy of H and O atoms is lower when they form the complex, i.e. H₂O.

As we have already discussed, reactions usually lead to an increase in disorder (entropy): two containers before the reaction contain two distinct gases and to separate them after the reaction *energy* is needed.

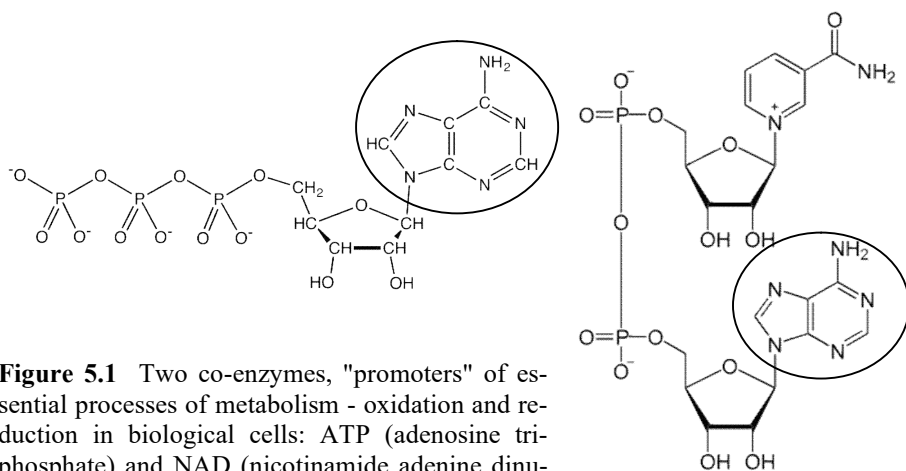


Figure 5.1 Two co-enzymes, "promoters" of essential processes of metabolism - oxidation and reduction in biological cells: ATP (adenosine triphosphate) and NAD (nicotinamide adenine dinucleotide). Both contain adenine, a nitrogenous base (with the NH₂ group), which is also part of DNA.

² To be precise, we should invoke the principle of minimum "action": a quantity defined as the integral of energy (kinetics minus potential) over time. This principle, formulated in 1744 by P.-L. Moreau de Maupertuis, explains, for example, the law of refraction in optics.

In a thermodynamic engine, the heat does the work, but in the end the waste heat is dispersed into the environment: in a long term, the temperature of the room and the engine equalize each other – entropy, i.e. the disorder, increases. Instead, life is the opposite of disorder: the planets using light (not very complex electromagnetic waves) and simple molecules (H_2O and CO_2) produce sugars, proteins, wood, aromas: everything except disorder. Life then tends to decrease entropy. Life consumes energy, but the difference between the beauty of a flower and the grayness of a rot is fulminant. Living structures show a very high degree of *organization* – whether it is a flower, a heart or a piece of DNA. Non-animate nature shows no ability to form complex but orderly structures: a snowflake is not complicated. How, then, to explain the appearance of life?

An encyclopedia of science explains the formation of complex structures as follows: "Smaller molecules, as a result of their movements in water and in continuous and reciprocal collision, tend to dis-aggregate, but others, the larger and slower ones, not only maintain their structure, but try to associate with each other and capture other smaller molecules by forming increasingly compressed molecular aggregates with well-defined architectures."³

Unfortunately, in our opinion, this is not an explanation but a *postulate*: sea waves move grains of sand in the same way as jellyfish. Spontaneous protein aggregates⁴ were the focus of the theory of life of the Soviet biologist Oparin (1894-1980).



Fig. 5.2. The formation of (a) snowflakes and FeS_2 pyrite crystals (b) can be explained in terms of chemical bonds, crystal symmetry (physics), fractals (mathematic), not to mention "self-organizing matter". SOURCE: NOAA; GK.

³ GAMPIERO FRIZZI and GUIDO FRIZZI, *Breve storia della biologia*, in: "Le basi della vita", La Scienza, La biblioteca di Repubblica, UTET, Roma 2005, p. 34.

⁴ We can add, ironically, that spontaneous aggregates form on uncultivated prairies, where the rolls of grass pushed by the wind grow larger; Such aggregates in the bedroom are formed from dust: a skein of garbage, and not an orderly structure.

The Belgian Nobel Prize winner, Christian de Duve (1917-2013), discoverer of numerous enzymes, believed that the birth of life was a "due" fact due to specific chemical reactions, which are very rapid. It is difficult to share this opinion: chemical reactions, i.e. the "jumps" of electrons from one orbital to another, are – yes, very rapid, on the order of 10^{-18} seconds, but not all. The very slow reactions, which are difficult to accelerate, are, for example, the formation of esters, i.e. the compounds of alcohol and acids, which give the wine its flavor. Another example of very slow reactions, which take several years, is the aging of polymers that makes them either brittle or soft.

Attributing to chemical reactions a special "tunning" (i.e. self-regulation) to facilitate the birth of biological life does not differ much from the requirement of tuning physical constants, to allow the energy cycle in stars and the birth of planetary systems: it is a mere postulate.

An attempt to explain the appearance of biological life by the laws of physics derives from the work on the thermodynamics of non-equilibrium systems, developed by another Nobel laureate, Ilya Prigogine (Moscow 1917-Brussels 2003). He was not concerned with thermodynamics "long to expire", that is, with systems in equilibrium, but with systems in transition. Prigogine observes that in transition phases systems can *minimize* entropy losses (i.e. trying to limit the growth of disorder, see par. 2.2).

To sum up, it seems that the concept of the appearance of complex biological structures is still missing, where the diminution of disorder reigns in comparison with the inorganic world, where disorder reigns. Aristotle wrote in *Physics* (222b, 20):

For it is clear that time may in itself be more the cause of destruction than of generation, as has been said before (for change is in itself the ability to bring things out of itself), while only accidentally can it be the cause of generation and being.⁵

This "accidentally" led Aristotle to formulate, even in *Physics*, the teleological cause: events happen *to* lead to *an end*. Then, the hypothesis deriving from Prigogine's work that the principles of mathematics could also allow maximum *order*, instead of maximum *disorder*, as required by the second law of thermodynamics, is new a *supposition*

⁵ ARISTOTLE, *Physics*, *op. cit.*, p. 113.

and not a *scenario* of procedures. Thus, the transition from chemistry to life remains a very serious conceptual "gap" (in Italian⁶: passo, breccia, lacuna, abyss, game) - conceptual, if not completely unbridgeable within the purely deterministic framework⁷. The question on the *cause* of the life is open.

5.3. The primordial broth

In 1953 Stanley Miller, a doctoral student in the laboratory of Nobel Prize winner Harold Urey, carried out an experiment that went down in history. Miller passed electrical discharges through a sealed glass ampoule, filled with water vapor, methane, ammonia, and hydrogen (which could correspond to the Earth's primordial atmosphere). The reaction products dissolved in the water: after just one day the water showed a pink color. After a week, reaction products were analyzed: surprisingly, five amino acids were found. Today in similar experiments ("Milley-Urey") numerous amino acids have been found.

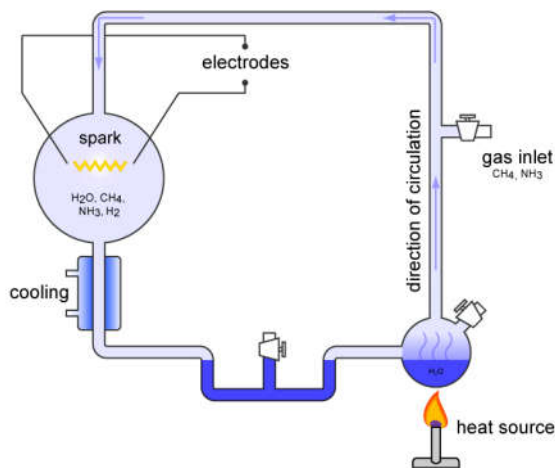


Figure 5.3. The scheme of Miller and Urey's experiment: electric discharges are applied inside a glass ampoule filled with water vapor, methane, ammonia and hydrogen. The products of the re-actions are cooled and trapped in the lower part of the apparatus. After a week of operation, several amino acids dissolved in water were found. SOURCE: Wikipedia; by Carny, id=611578.

Miller's experiment aroused great interest, it was greeted with applause in the countries of the Soviet bloc (including Poland, at the

⁶ The Bantham New College Italian & English Dictionary, New York, 1976.

⁷ And with this we find a synergy with Prigogine, who considered determinism the negation of the arrow of time ("determinism is fundamentally a denial of the arrow of time"); https://en.wikipedia.org/wiki/Ilya_Prigogine.

time): life was born by itself, it no longer needs a creator⁸. Unfortunately, more than 50 years after Miller's discovery, not much progress has been made: from single, somewhat random amino acids we have not been able to build larger aggregates, i.e. proteins.

Then, to build functioning proteins, a particular order is needed. Today we can encode it on the computer's hard drive (that's too many numbers to write on paper): a few billion years ago, the only way to write chains of 3,300,000,000 digits, in a thickness of single nanometers (10^{-9} m) was DNA.

Today, the most promising methods for synthesizing amino acids in a controlled way are reactions at very low temperatures, carried out on dust grains, such as cosmic reactions. The French colleagues⁹ managed to synthesize glycine, a simple amino acid, from acetic acid and ammonia (which in turn are found in outer space) using low-energy electrons. But more than ten years later, there has been no further progress.

5.4. Life from comets?

It was feared (in popular belief) that comets would bring disasters. One of the most beautiful comets, Halley's, returns every 80 years or so and was (probably) immortalized by Giotto in the fresco of the Nativity in the Scrovegni Chapel in Padua. Scientists today are trying to understand whether it was not comets that brought life to Earth. In fact, several space probes have been directed towards comets and in 2014 one even landed on a comet.

Comets are very cold and dirty snowballs, a few kilometers wide. When they arrive near the Sun, they begin to evaporate, leaving two tails: one behind, yellowish, made up of dust lost along the way, another, blue, straight, of heated gases, see Fig. 5.4b.

Astronomers believe that comets come from the distant confines of the Solar System: the Voyager 1 probe, which in 2013 had reached the

⁸ Scientists who "believe" in life born by pure chance are like those who, before the invention of the microscope, were convinced that microbes, fleas, flies, etc., grew by themselves in pure water.

⁹ L. AMIAUD, *Electron induced processes on mixed molecular ices*, Institut des Sciences Moléculaires, Orsay, 2015, <http://www.ismo.u-psud.fr/spip.php?article1522&lang=fr>.

distance of 130 astronomical units¹⁰ from the Sun and crossed the edge of the solar wind, found no trace of comets. In reality, the cloud containing comets, hypothesized by Jan Oort, should be a thousand times farther away, almost at a distance of one light year from the Sun. On the other hand, looking at the beautiful images of supernovae (see photo 2.15), the existence of the Oort cloud is plausible: distant, cold and full of comets.

Probes have already been sent to comets in the past: one bombarded the comet with a projectile and had studied the appearance of the released gases. The other, "Stardust" went through the tail of dust, stretching a trap like a tennis racket, collecting dust and returning the trap to Earth. Thousands of micro-powders were found and in them various minerals, both those that exist in the earth's crust and molecules of probable extra-solar origin. It seems that comets collect space microjunk.

In 2014, the European agency ESA "landed" the "Rosetta" probe on comet 67P/ Churyumov-Gerasimenko (names of the Russian astronomers that discovered it in 1969). The 67/P resembles a dog bone, 4 km long. The probe jumped a bit before docking well and as a result found itself partially in the shade: soon the solar panels stopped working. But before expending, "Rosetta" managed to analyze the surrounding gases.

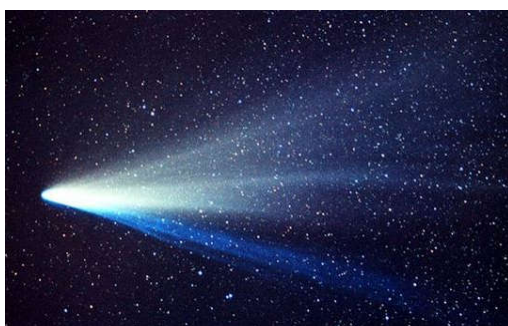


Figure 5.4. (a) Giotto saw Halley's comet in 1301 and painted it on the fresco in the Scrovegni Chapel in Padua. (b) Comets spread two comatories as they pass through them – one bluish, due to vapours, another yellow, due to dust left in space. SOURCE: Wikipedia (Capella Degli Scrovegni), courtesy of the Municipality of Padua; ESA.

¹⁰ Recall that the astronomical unit is equivalent to the distance of the Earth from the Sun (150 million km) and instead 1 light year = 63241 u.a.

In addition to water (H_2O) and methane (CH_4), ammonia (NH_3), hydrogen sulfide (H_2S), hydrogen cyanide (HCN), formaldehyde (H_2CO) were found: all very smelly gases, which in biology arise from the putrifaction of organic substances, in particular proteins. Unfortunately, for chemical reactions in reverse, i.e. from simple gases to amino acids, the road is not easy.

But the diversity of molecules on the comet is nothing compared to interstellar clouds that contain many molecules, including organic ones. There's even a cloud full of ethyl alcohol, only it's a few light-years away.

5.5. On a very hot Earth

The first solidified rocks were probably formed 4.2 billion years ago, still on the semi-liquid Earth. The Archaean era (or rather: "aeon") is conventionally extended from 4 to 2.5 billion years ago and is followed by the Proterozoic eon (between 2.5 billion and 0.542 billion years ago). Between the Archaean and the Proterozoic there was a huge leap: in life forms, in the atmosphere, in the hydrosphere and even in the litho-sphere (i.e. geological forms¹¹).

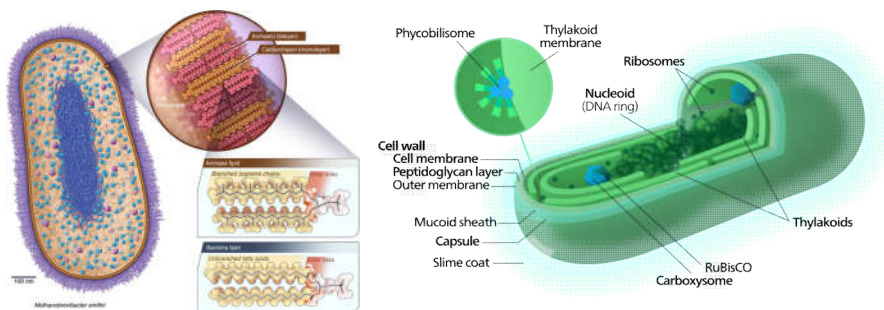


Fig. 5.5 (a) *Methanobrevibacter smithii* belongs to the kingdom Archaea lives in the human intestine, where it produces methane by digesting polysaccharides; it has a very simple anatomy: a tangle of DNA in the center and a very primitive cell membrane, not yet based on lipids; (b) The structure of the blue-green bacterium (cyanobacterium) is much more complicated: it contains "subcells" specialized in certain functions, such as photosynthesis or replication (ribosomes). SOURCE: Wikipedia.

¹¹ Some estimates say that almost half of the minerals (more than two thousand), not counting rocks such as limestone and marble, are of organic origin.

This type of life was completely different from the forms that dominate the earth today: there was no free oxygen in the air or in the water, then the metabolism based on the extraction of energy from the processes of "combustion" did not work. The opaque atmosphere did not allow photo-synthesis. Early life forms had to derive energy from ineffective bio-chemical processes, such as the formation of pyrite (Fe_2S) - from hydrogen sulfide (H_2S) and iron ions dissolved in water. Reactions in this way could take place in the "black fumaroles" – the hydrothermal vents in the depths of oceans, in volcanic zones. Even today we find very strange forms of life there¹².

The alternative hypothesis is the formation of simple organic compounds, again in the areas of underwater volcanoes, directly from hydrogen and carbon monoxide, in reactions catalyzed by nanostructures (?) of sulphur, nickel and iron.

An example of the bacterium (or more properly non-bacterium, but a more primitive organism, now classified in the kingdom of Archaea) that still exists today is the *Sulfolobus solfataricus*, found for the first time in the solfatara of Pozzuoli. It grows best at a temperature of 80° Celsius, in an extremely acidic environment (between pH = 2 and pH = 4) and requires the sulphur on which its metabolism is based.

The great interest in this species derives from the fact that its genome was recently (in 2001) resolved. It contains¹³ 2,992,245 nucleotide bases encoding 2,977 proteins. A third of the *S. solfataricus* genome encodes proteins that do not correspond to other living beings. The remaining 40% are proteins specific to the Archaea kingdom, 12% in common with bacteria, and only 2.3% are proteins shared with eukaryotic organisms (i.e. cells with a nucleus containing DNA and other "organelles").

S. solfataricus uses semi-inorganic enzymes (ferredoxines, i.e. protein compounds with iron and sulphur) for metabolism rather than NAD from other organisms (see fig. 5.1). But a similar molecule of

¹² This is how Nick Lane describes these environments: "This bizarre and isolated world looked like a vision of hell and turned out to be full of sulphur and invaded by the unpleasant smell of rotten eggs of hydrogen sulphide coming from the black fumaroles. Only the troubled mind of Hieronymus Bosch could have imagined the giant tubeworms, deprived of mouths, digestive tracts and anuses in adulthood, and the eyeless shrimps, swarming in innumerable multitudes on the ledges under the mouths of chimneys, grotesques like the biblical plague of the locusts." N. LANE, *The Inventions of Life. The ten great stages of evolution*, il Saggiatore, Milan, 2012, p. 25. Original: *Life Ascending. The Ten Great Inventions of Evolution*, [*]

¹³ https://en.wikipedia.org/wiki/Sulfolobus_solfataricus (accessed 10/10/2018).

iron and sulphur, incorporated into specific proteins, serves for the activity of the human thyroid. This is one of the cases of the "saving" of bio-chemical solutions, which nature has experienced over billions of years.

In another primordial organism, *Archaeoglobus* lives in boiling oil wells (it proliferates best at 83°C) and obtains its energy from the chemical reaction of reducing¹⁴ sulfates (SO_4^{-2} ions) into sulphides (to the S^{-2} ion, e.g. in the aforementioned H_2S). This is how the oxygen is released. Then, in an inorganic reaction, the formation of solid sulfur is possible: $16 \text{HNO}_3 + 24 \text{H}_2\text{S} \rightarrow 16 \text{NO} + 3 \text{S}_8 + 32 \text{H}_2\text{O}$. Otherwise, the S^{-2} ion can form compounds with metals: with mercury cinnabar (Hg_2S), with lead - galena (PbS), with iron - pyrite (FeS_2 , called gold of stupid, see figure 5.2b).

Remembering the atmosphere of Venus (full of sulfuric acid H_2SO_4) – who knows if it was not the *Archeoglobus* (or its predecessors) that freed the Earth from clouds of sulfuric acid and sent the first rays of sunlight to the surface.

The genome of *Archaeoglobus fulgidus* also contains 2,178,000 bases and remains largely enigmatic: about 1/4 encodes proteins whose functions are unknown. The genome seems full of superfluous duplications, but the proteins produced are not identical¹⁵.

Also belonging to the kingdom of Archaea is a "bacterium" that produces methane from CO_2 and H_2 , *Methanobrevibacter smithii*¹⁶; it is also present in the human intestine where it helps digest polysaccharides¹⁷. It has a very simple construction: a DNA package and a cell membrane made of isoprene rather than lipids (as in more advanced organisms, starting from bacteria). Its structure is presented in Figure 5.5a. Who knows if our tenant-helper is not a remnant of the Archean era? It would be another argument for the "rationality of nature": the same solutions billions of years later. But does this *razon* really derive from a purely atomic world?

¹⁴ The reduction of sulphates is coupled (in oil wells) with the oxidation of hydrocarbons.

¹⁵ <https://en.wikipedia.org/wiki/Archaeoglobus> (accessed 20/12/2018).

¹⁶ https://en.wikipedia.org/wiki/Methanobrevibacter_smithii (accessed 20/12/2018).

¹⁷ This archaeo-bacterium could not exist in an inorganic environment, because energy is obtained from the "digestion" of carbohydrates.

5.6. The Green Planet

In the middle of the Archaean, new and more complex forms of life appeared: bacteria. Although they are still unicellular organisms, their structure is more complicated, with the division of functions, but still without a separate nucleus for DNA (see Fig. 5.5b). Among the first bacteria to appear, perhaps as early as 2.5 billion years ago, are the blue-green ones, called cyanobacteria.

The geological evidence of the first forms of life derives from the formations of sandstones, called stromatolites: grains of sand bound with organic material. Stromatolites, which most likely testify to the presence of photosynthetic bacteria, date back to about 2.5 billion years ago.¹⁸ It is debated whether older rocks, such as those from Australia (3.4 billion years ago) or Greenland (3.7 billion years ago¹⁹), also had organic formation.

Cyanobacteria show some characteristics that suggest that they come from the era between anaerobic and aerobic life. For example, they have the ability to fix atmospheric nitrogen²⁰ in ammonia (which in turn forms amino acids). The characteristics of cyanobacteria are also evidence of different physical conditions on the planet: cyanobacteria contain, for example, other pigments, complementary to chlorophyll, such as phycocyanin, which absorbs yellow light (620 nm, compared to 650-660 for chlorophyll): today's biological life bears the imprints of pre-pre-history.

The great oxygenation event (GOE) occurred about 2.5 billion years ago, certainly coinciding with the appearance of cyanobacteria. But what were the causes of GOE – lack of nickel that stopped the proliferation of methanogenic bacteria (one of their enzymes needed for this element), a global glaciation, the feedback effects linked to the formation of ozone – we do not know. Without a doubt – the presence of oxygen in the atmosphere changed everything – from the chemistry of oceans to the geology of mineral deposits. We are not talking about biological life: instead of very complicated (and not very effective)

¹⁸ <https://en.wikipedia.org/wiki/Collenia> (accessed 22/10/2018)

¹⁹ A.C. ALLWOOD, *Evidence of life in Earth's oldest rocks*, «Nature» 535 (2016), p.500.

²⁰ Today, plants are unable to use atmospheric nitrogen and need nitrogen underground. Few plants, for example legumes, live in symbiosis with nitrogen bacteria, capable of fixing atmospheric nitrogen.

schemes of oxidation and reduction of sulphates, nitrates, etc., the cycle of metabolism based on carbon compounds enters.

After GOE, the energetics of living beings became standard: synthesizing hydrocarbons (proteins, fats) and burning them in an oxygenated atmosphere when needed. "Subcells" specialized in these operations have been formed – mitochondria, with their autonomous genetic heritage – simple but robust.

Meanwhile, the planet, seen from the sky, began to appear green: even today, cyanobacteria contribute to half the volume of photosynthesis in open oceans. The metabolic versatility of cyanobacteria placed them between the two eras of the Earth: without and with oxygen in the atmosphere. And the change was caused, in large part, by the bacteria themselves.

5.7. In the depths of the oceans

The first forms of life were born in the oceans; there too the most evolved organisms developed, with well-specialized organs, as we know them today: not only vertebrates (fish, amphibians, reptiles) but also the ancestors of insects. Examples of convergences, living fossils, parallelisms in evolutionary solutions are the surprising vaults, see fig. 5.6 for Arthropods. Following the example of this group (*phylum*), which has more than two million species, it is surprising how "nature" experiments with different solutions, overlapping and in different environments.



Fig. 5.6. Despite the enormous variety of animals, certain forms resemble each other millions of years apart. (a) Trilobites reigned in the seas from 550 million years ago, in murky, oxygen-poor waters. (b) Today, a segment-like structure and one pair of legs per segment possesses the pill bug (*Armadillidium vulgare*) which is nourished by organic remains, including wood; It colonized the earth about 500 million years ago. (c) The Madagascar whistle cockroach (*Gromphadorhina portentosa*) unlike other cockroaches does not have wings; Fossils of cockroaches date back to 350 million years ago. SOURCE: (a) Hewelianum, Gdańsk, GK, (b) MK; (c) Wikipedia.

The common pill woodlouse, fig. 5.6b, an arthropod a little more than a centimeter long, lives in Europe in the humid corners of vegetable gardens and in Africa on the arid deserts. Cockroaches, annoying winged insects, do not fly in Madagascar, but whistle. In simple logic, only one winning species would be enough for each environment, not all this wealth.

Trilobites, which first appeared about 550 million years ago in the area of Siberia, reigned in the seas until 250 million years ago. They were arthropods with complex exoskeletons, up to 30 centimeters long and occupied different ecological niches, from scavengers to predators. For hundreds of millions of years, these life forms proliferated only in the oceans: the oxygen content in the atmosphere was low, there was no ozone layer, and ultraviolet radiation could be deadly.

Trilobites had primitive eyes, made from thousands of transparent calcite crystals (CaCO_3). With their well-defined structure (meaning little variable), at the end of the Paleozoic they could not withstand the competition of the new evolutionary "solution", the endoskeleton of fish that allowed rapid movements.

The first vertebrates probably date back to the time of trilobites, about 500 million years ago²¹. Relatively early, over the course of a hundred million years, the first "hybrids" appeared, i.e. animals with the characteristics of both fish and amphibians (or maybe reptiles, fig. 5.7). The finds of these forms of "transition" are rare, because these animals were not very suitable for the environment, so few in number. Compared to today's species, they look like biblical "sea monsters".



Fig. 5.7. (a) A transitional form between fish and amphibians – a tiktaalik recently discovered in Canada and dating back to 375 million years ago. (b) God created the great monsters of the sea, *Tapis de la Creació* in Girona. Source: KEVIN JIANG, The University of Chicago, <https://tiktaalik.uchicago.edu/press/>; Wikipedia.

²¹ JUN-YUAN CHEN, DI-YUNG HUANG & CHIA-WEI LI, *An early Cambrian craniate-like chordate*, «Nature» 402 (1999), p. 518.

The tiktaalik, *Tiktaalik roseae* lived 375 million years ago and was an intermediate form between fish and amphibians. His footprints in the rocks were found in 2006 in Antarctic Canada which at that time was in a tropical area. The name means a type of cod in the Innuite language. It is not the only form of transition to tetrapods, but it is the first with a well-developed pelvis, which indicates an evolutionary path towards dinosaurs. Other intermediate forms are rather typical for amphibians.

Was there a single path of evolution or several others in parallel? It seems that at all times, in all the ever-changing environments, "the waters of a multitude of living things were swarming," as *The Bible* says.

5.8. DNA – a little hard, a little soft

The genetic code, enclosed in the very long double helix of DNA (in onion cells and 5 cm long) is the basis both of reproduction from one generation to the next (it means the preservation of characteristic traits of a biological species) and of the variability of species. DNA must be inflexible enough for changes not to degenerate during an individual's lifetime (because otherwise genetic modification occurs, i.e. cancer - terrible suffering), but variable enough to allow biological evolution over time. The two objectives are opposed.

The discourse on the scale of energy in atomic processes (and in the spectrum of sunlight²²) serves to understand one of the problems that have worried all thinkers, from St. Thomas and Leibniz to Charles Darwin: why do evil and suffering exist? Darwin in his *Autobiography* (1876) wrote that it is difficult to understand why God, the creator of the universe, omnipotent and omniscient to our minds, of unlimited benevolence, allows the sufferings of millions of inferior animals, for an infinite time²³. In fact, if from the point of view of human ethics

²² The visual spectrum, from 380 nm to 760 nm in terms of wavelength, extends from 1.63 to 3.26 eV in terms of energy (short waves correspond to the higher energies).

²³ «all other sentient beings, and these often suffer greatly without any moral improvement. A being so powerful and so full of knowledge as a God who could create the universe, is to our finite minds omnipotent and omniscient, and it revolts our understanding to suppose that his benevolence is not unbounded, for what advantage can there be in the sufferings of millions of the lower animals throughout almost endless time?» CH. DARWIN, *Autobiografia*, ed. Nora Barrow, Collins, London 1958, p. 90.

one could justify the existence (and necessity) of diseases and disasters, as Darwin writes, animals do not need moral perfection. And Darwin himself intuitively answers: these sufferings are used for "natural selection".²⁴

Then the question comes back even more acutely: does natural selection also work in the case of man? It would be an ethical reductionism. No! We simply share the same biological structures with animals, including DNA. The two strips of the double helix are built with strong, *covalent chemical bonds*, like these in the N_2 molecule. Instead, the stripes are linked to each other with de-boli bonds, which exchange not an electron but a proton ("hydrogen" bonds). The delicate links between the two strips allow the so-called sexual reproduction, that is, the interchange of genetic heritage of the two parents. But the whole structure of DNA remains delicate when compared even with ultraviolet light²⁵: for this reason mutations arise.

Mutations from the point of view of the biological species are beneficial. As Darwin says, they allow us to adapt to changes in external conditions (physical, chemical and also due to the presence of other organisms, such as predators).

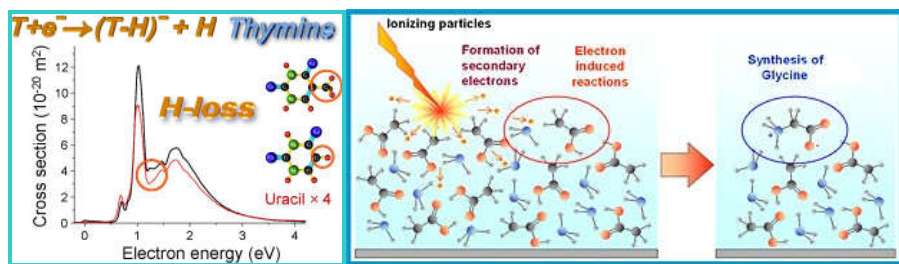


Fig. 5.8. It is the low-energy electrons that destroy the bonds between the nucleotic bases, allowing the "swinging" fragments to create new jumpers: mutations (P. SCHEIER, Universität Innsbruck). (b) The same slow electrons can (on a particular surface in a high vacuum and at low temperature) induce the synthesis of CH_3COOH (acetic acid) and ammonia (NH_3) into glycine, a simple amino acid. (A. LAFOSSE, Université Paris Sud).

²⁴ «This very old argument from the existence of suffering against the existence of an intelligent first cause seems to me a strong one; whereas, as just remarked, the presence of much suffering agrees well with the view that all organic beings have been developed through variation and natural selection.» CH. DARWIN, *op. cit.* p. 118.

²⁵ It was discovered a few years ago (LEON SANCHE, 2001) that even electrons, and surprisingly low energy, can cause alterations to DNA.

But from an individual point of view, damage to the DNA helix often means a tumor. Thus, a delicate balance between the chemical energies of bonds and external factors (such as radiation) allows a certain stability of the individual organism, but a plasticity of the species, when external conditions require it.

God did not create a stable world, fixed for billions of years, but an environment rich in constant (and exciting) progress. The perpetual "travel" in time of the entire universe, of the galaxies, of the flat Earth, of organic life, is no less interesting than a pilgrimage to distant lands.

5.9. Genes: a bit of combinatorics

The DNA code in all living organisms uses exactly the same components and the same mathematical coding rules. The discoverer of the structure of DNA, Francis Crick, wondered why there are no codes made differently in nature. "The obvious answer is that all organisms existing on Earth are descended from a common ancestor, in which the code was already fixed."²⁶ By whom was it fixed? Or did it come from outside? What only shifts the demand.

Nick Lane has suggested that the (winning) rules of DNA construction were established around one of the many hydrothermal vents in the distant past. So all organisms use the same 16 amino acids whose production is encoded with the 4-letter sequences of the DNA alphabet. How many letters do you need? To distinguish 20 amino acids, it is necessary to use sequences consisting of a minimum of 3 letters. This sequence (a "codon") is the building block for protein synthesis. Combinatorial mathematics explains it.

To encode 16 amino acids with 4 letters, sequences of at least 3 letters are needed. In combinatorics, these sequences are called "dispositions with repetitions". The number of arrangements, allowing the repetitions of the same letter, is n^k , where n is the total number of elements (in our case $n=4$) and k is the length of the sequence ($k=3$). So the total number of dispositions is $4^3=64$. From here we must remove the sequences of three identical letters (which are not distinguishable when read upside down or backwards) and reserve at least one se-

²⁶ N. LANE, *op. cit.*, p. 52.

quence for the codon at the end of the sequence (the stop). Three letters are enough for 20 amino acids.

Nature, on the one hand, avoids redundancies, on the other allows a certain flexibility. In the sequence of 3 letters, the first one already determines that a chemical precursor will be used in the synthesis of amino acids. The latter seems to determine the water-soluble, basic or acidic character. The third letter appears to be redundant (it does not affect the synthesis of alanine, glycine, etc.), but the letters *A* or *D* act as a stop.

In this first part of the twenty-first century, molecular biologists have already synthesized 40 artificial amino acids that can replace the natural ones in proteins. By constructing 4- and 5-letter "codons," they also encoded ways of synthesizing some artificial amino acids for living cells.

These possibilities only fuel other questions: given the near-redundancy of the third letter in codons (and certain amino acids), perhaps early life forms used only 2-letter codons? Going from 2 to 3 letters, however, is easy at the conceptual level ($3=2+1$), but not from a practical point of view: it would mean that the whole long code would have had to undergo a variable translation. It would be like closing a zip made from two strips of different grains: something impossible to perform. Was this change fixed *a priori*? By whom?

5.10. A perfect code?

The DNA code, with its redundancies and/or omissions (more than 20 amino acids could be encoded with 3-letter codons) seems a bit random. In fact, 15 amino acids can already be coded with 2 letters. The function of the third letter is not clear: it seems to have been added by chance.

In the 1990s, two British molecular biologists, Lawrence Hurst and Stephen Freeland, using fairly powerful computers, examined a multitude of codes constructed in different ways, concluding that "the real genetic code is better than a million randomly generated alternative codes."²⁷ The real code is the most resistant to possible mutations and protects us from serious errors in the construction of proteins resulting

²⁷ *Ibid.*, p. 56.

from these mutations. The code is redundant, but for this very reason it is much more secure.

Nick Lane comments on the open questions: "Far from postulating the divine plan, optimization can be explained through the only functioning of selection."

With selection, however, another problem arises: to synthesize proteins, putting amino acids in a precise order, DNA is needed, which nevertheless has the structure of a protein. Chicken or egg first? Scientists are trying to get out of this trap by studying the role of messengers between DNA and proteins. But Nick Lane himself admitted that "this whole scenario is undoubtedly conjectural, and there is still little evidence to support it" (p. 58).

5.11. The Ten Inventions of Life

Nick Lane listed ten inventions of life. The first is the life itself, almost certainly born in the primordial oceans, and with the atmosphere devoid of oxygen. Follow:

- 2) the code of life, i.e. DNA;
- 3) photosynthesis (different pigments, not only chlorophyll, active in the transfer of electrons into the appropriate biological molecules);
- 4) the complex cell: an aggressor who has engulfed other cells, simpler but specialized in specific functions;
- 5) sexual reproduction, as an effective exchange of DNA fragments;
- 6) movement, which started from unicellular organisms, inventing many ways of locomotion in all environments ("let birds fly above the earth");
- 7) sight, or more precisely the specialization of certain skin cells in converting the signal of electromagnetic waves into electrical signals;
- 8) the warm blood that has made it possible to colonize the most remote corners of the Earth.

The last two stages raise some perplexity:

- 9) consciousness, which is difficult to trace back to blind evolution;
- 10) the death of the individual, as the price of genetic "progress".

The first three topics – the formation of life in the very particular environment, the flexible mathematical code for the slow variation of

species and the appearance of electro-photo-active organic pigments – we have already discussed. Locomotion remains very interesting – not only like the limbs of grasshoppers and dogs, but at the cellular level, indeed – molecular. It was locomotion that allowed new environments to be colonized, even for primitive organisms such as paramecium (*Paramecium caudatum*). It moves thanks to the edges that cover the surface of its cell in the shape of a shoe. (Cilia of the same type cover the mucous membrane in the human bronchi.)

Recently a model of locomotion was published of another group of protozoa, which have a single, large edge that rotates like the propeller of a ship. The construction of this nano-helix includes "toothed" wheels on the edge and in its bearing inside the cell and seals on this bearing, see fig. 5.9a. The processes of metabolic "combustion" power this nano-engine. Other recent studies, done by theoretical and experimental physicists, have shown that this helix-edge cannot be too long or too rigid and that it must be rotated with the right speed so as not to twist. It takes a lot of scientific work to understand the secrets of the biological world.

Transport processes also take place inside the individual cells, and not only chemical but just as mechanical. Inside the cells there are highways to carry certain proteins from one corner to another. But tugboats are also needed. Kinesin is a braid-shaped protein with two "feet" free to move.

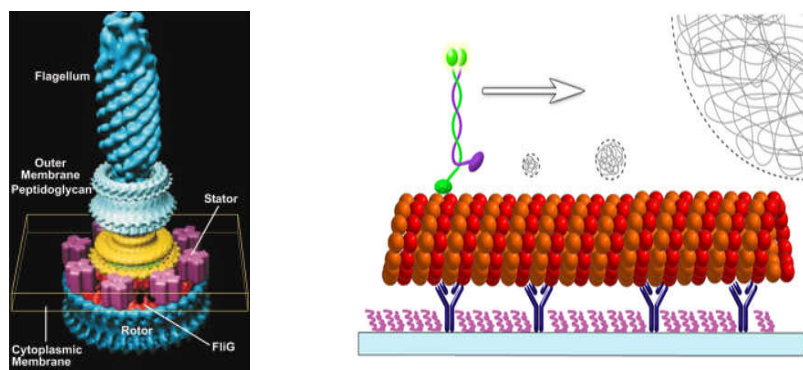


Fig. 5.9. (a) a "flagellum" of an *Escherichia coli* bacterium is a real nano-helix that rotates thanks to the gears inside the cell. (b) Kinesin's "step" along the highway inside a cell is about 8 nm, every 10 ms; Kinesin can carry very heavy loads that it (K. SOZAŃSKI *et al.*). SOURCE: APS, Wikipedia.

The cycles of oxidation (the reception of an electron) and reduction (the release of an electron) from an ATP molecule (see Fig. 5.1) allow the kinesin to extend a foot and move, and with it also carry loads. The single step is 8 nm (the distance of a few atoms), takes 10 milliseconds and the maximum towed load amounts to 0.1 femto-newton (i.e., equivalent to the weight of a thousand molecules of some complex protein) – a real cell truck²⁸.

Another mechanism is used in muscles. Myosin, also a protein shaped like a double braid, shortens when an electrical signal arrives²⁹. The description of the process is so complex, that a translation is not yet (30/10/2018) found in the Italian Wikipedia. In the English version we talk about the ion gates (Ca^{2+}) of neurons, which are activated under the electrical potential, releasing acetylcholine, which in turn binds to nicotinic receptors in the membranes of muscle cells and triggers a wave of release of sodium and potassium ions, and the subsequent contraction in the entire muscle fiber³⁰. The myosins of different animals are not identical, but despite this, a wide compatibility is observed: the myosin of the rabbit can bind to the actin (a protein that collaborates in the transition of signals) of the amoeba.

²⁸ K. SOZAŃSKI *et al.*, *Small Crowders Slow Down Kinesin Stepping by Hindering Motor Domain Diffusion*, «Phys. Rev. Lett.», 115 (2015) 218102; 10.1103/PhysRevLett.115.218102.

²⁹ Not only does myosin change size in the presence of electrical signals. Even a quartz crystal shrinks in the electric field. Thus, or rather in reverse, how the gas ignitor works – the spark is triggered, when the quartz crystal is crushed.

³⁰ «The sequence of events that results in the depolarization of the muscle fiber at the neuromuscular junction begins when an action potential is initiated in the cell body of a motor neuron, which is then propagated by saltatory conduction along its axon toward the neuromuscular junction. Once it reaches the terminal bouton, the action potential causes a Ca^{2+} ion influx into the terminal by way of the voltage-gated calcium channels. The Ca^{2+} influx causes synaptic vesicles containing the neurotransmitter acetylcholine to fuse with the plasma membrane, releasing acetylcholine into the synaptic cleft between the motor neuron terminal and the neuromuscular junction of the skeletal muscle fiber. Acetylcholine diffuses across the synapse and binds to and activates nicotinic acetylcholine receptors on the neuromuscular junction. Activation of the nicotinic receptor opens its intrinsic sodium/potassium channel, causing sodium to rush in and potassium to trickle out. As a result, the sarcolemma reverses polarity and its voltage quickly jumps from the resting membrane potential of -90mV to as high as +75mV as sodium enters. The membrane potential then becomes hyperpolarized when potassium exits and is then adjusted back to the resting membrane potential. This rapid fluctuation is called the end-plate potential. The voltage-gated ion channels of the sarcolemma next to the end plate open in response to the end plate potential. These voltage-gated channels are sodium and potassium specific and only allow one through. This wave of ion movements creates the action potential that spreads from the motor end plate in all directions.» FONTE: https://en.wikipedia.org/wiki/Muscle_contraction.

The invention of sexual reproduction was a factor that had greatly improved the possibilities of adaptation of biological organisms to variable external conditions. The combination of two genomes, with complicated procedures of DNA ribbon splitting, dilation, substitution, inversion etc. ensures that grandchildren look more like grandparents (or uncles) than parents. Don't worry! The similarity will return in the second generation.

The eyes, very primitive from trilobites (calcite crystals) over millions of years have specialized for many different needs. Insects, with their very primitive brains, have eyes made like detectors of elementary particles: many photo-multipliers positioned next to each other (like a honeycomb). The bee does not need to see the green color, but it is necessary to distinguish white flowers (for us) of the apple tree, pear and plum. Then, in the ultraviolet light the nectar shines in the center of the flower, so the bees can aim directly there. The viper needs to see the mouse warm even in the dark, so it uses infrared detectors (and it stays cool, for the best contrast with the prey).

Strangely, the same pigment of the human retina (rhodopsin) is found in the colorless shrimp of fumarole springs. The shrimp has no eyes but only two rhodopsin lobes placed on its back. This strange formation allows the crayfish to roughly identify very faint light sources, with sensitivity 7 million times greater than the flatly formed eyes of their larvae³¹.

The same protein as the human lens is found in the brain of a marine invertebrate, long ascidian (*Cioma intestinalis*). "We don't know what he is there to do, but it is not relevant to us. What matters is that the same genes that direct the formation of the lens in vertebrates also control the activity of this protein; in the ascidia they have a function in the brain as well as in the eye."³²

It seems that "nature" has fun experimenting with different possibilities. The wealth of choices and the parallelism of the solutions is surprising. For those who don't like ATP metabolism, there is NAN (fig. 5.1) in alternation. If you don't like red blood (which requires a protein with the iron ion), here is the blue blood of the octopus (*Octopus macropus*), which contains the copper ion. We can attribute this wisdom to "nature," or to a transcendental Mind, from which nature

³¹ N. Lane, *op. cit.* p. 177.

³² *Ibid.*, p. 188.

draws to make use of the different solutions. The continuity of life through the last 3-4 billion years shows that this Wisdom greatly exceeds the solutions "currently in use".

Nick Lane remains more reserved. Commenting on the presence of pre-eyes in some protozoa, he writes as follows:

Whether the animals' eyes developed from them directly or indirectly (through a symbiosis), in this teeming and little-known microcosm, is an open question. Whether this happened as a predictable step or as a scandalous fluke, we cannot say. But this kind of question, at once specific and universal, is the very substance of science, and I hope it will inspire a new generation of scientists with their eyes fixed on their stars³³.

To the "inventions of life" Nick Lane adds consciousness and death. It is convenient to leave these last topics to the discussion of *creatures* that are able to feel emotions superior to biological ones (i.e. superior to fear, hunger, pain, reproductive instinct), that are able to remember, predict, imagine, reflect, i.e. man.

5.12. Why all this abundance?

Looking at the very primitive metanogenic archaeo (pre-bacterium) cell found in the human gut, one marvels that most of this tiny organism occupies the DNA code. What is the 3 million letter ribbon for? *Methanobrevi-bacter* performs few functions: it cuts polysaccharides (starch), burns the resulting sugars and with the energy obtained removes the superfluous hydrogen by binding it to the remains of CO₂, thus producing methane. No eyes, no movement, no photosynthesis: warm, food-rich, safe environment. The vast majority of DNA heritage is completely unused. But *it could* be useful.

Methanogenic bacteria could probably also exist in other environments, not just in the gut. Indeed, billions of years ago they could bind hydrogen and atmospheric CO₂, producing methane and water and obtaining energy from this type of reaction. A quarter of the genome of *Methanobrevibacter smithii* encodes functions completely unknown to scientists.

³³ *Ibidem*, p. 191.

The same with *Archaeoglobules*: they use energy from an unprofitable reaction, the chemical reduction of sulfur³⁴. The reaction certainly comes from the times when there was no oxygen in the air (3 billion years ago). But *Archaeoglobule* "digests" petrol, and this was formed (for example deposits in Canada) just a hundred *million* years ago. So did the archaean have to acquire or produce, or invent, or inherit the piece of DNA with the information on the metabolism (oxidation) of hydrocarbons?

Were these 2 billion years on Earth without oxygen? Unfortunately or fortunately: yes! In the meantime, the moon was formed³⁵, taking on its far side the greatest number of meteorite impacts, the earth cooled and the inner core of solid iron was formed creating the protective magnetic field, the atmosphere became transparent to sunlight, etc. It was the evolution of the Earth that forced changes in life forms. In this way, geological and biological history were in agreement at all times.

In the history of planet Earth there were several global catastrophes:

- 1) the (probable) very long Hononian glaciation at the end of the Archaean (2.4-2.1 billion years ago),
- 2) the catastrophe at the end of the Paleozoic (241 million years ago), probably due to the reappearance of sulphur in the atmosphere, which caused the extinction of 81% of marine species and 70% of terrestrial vertebrates,
- 3) the disappearance of the dinosaurs (65 million years ago, due to the fall of a meteorite). All these disasters have not only not led to the end of life, but have even allowed the appearance of new species, better prepared for the already evolved environmental conditions.

³⁴ Sulphur, being analogous to oxygen, presents, in principle, similar reactions. But as the number of orbits increases (oxygen has 2, sulphur – 3), the energy between external electronic levels (which govern chemical reactions) decreases. Thus the "biological" cycle of sulphur yields little energy compared to cycles based on carbon and oxygen.

³⁵ "And God made the two great luminaries: the major luminary to preside over the day, and the minor luminary to preside over the night, and the stars." *Genesis* 1:16: the fourth day.

But couldn't God "prepare" the Earth ready-made? Yes, that he could. But He has already made a material universe, all in one whole in a 10^{-32} seconds. A little patience, please.

Seriously: in the course of evolution, organisms have developed and inherited a very vast heritage, potentially useful in the ever-changing conditions of life on Earth. Man also contributes to these changes.

5.13. A blind evolution?

Charles Darwin, endowed with an extraordinary capacity for observation (and talent as a painter), caused³⁶, perhaps unintentionally, a profound division in our vision of the world: it was not a Creator, but a blind chance who developed the richness of the life forms that surround us. But he did not express himself in this way: in the conclusion of his most important work, *The Origin of Species*, he spoke of a "breath of life".

Despite more than 150 years since the publication of Darwin's work, the theory of evolution has many gaps, of which we list a few: convergence, parallelism, multi-directionality. Bees flap their wings 500 times per second, carrying loads of honey greater than their own weight. But in the hive, the wings must be spread, to save space. Then, between the anterior and posterior segments there is a very complicated hinge, see fig. 5.10a. The number of random combinations of mutations to find an adequate match between two segments would be enormous. Has something driven the evolution in two segments?

All frogs lay their eggs in water, which once fertilized develop into tadpoles. All except for a species of Guinea, *Nectophrynoides occidentalis*, which lives in the limited area a few kilometers around Mount Nimba. This frog remains pregnant for 9 months, in the meantime it hibernates due to drought and with spring the small frogs are born already similar to the adult specimens. An unexpected *convergence* of "evolutionary" solutions between the frog and mammals.

³⁶ Personally, I think, after reading his *Autobiography*, that Ch. Darwin did not expect such profound consequences of his work. As a young man he wanted to become a pastor. In 1904 he was openly asked if he was a believer; having to choose, he declared himself an atheist.

In the caves of Mexico lives a salamander that becomes an adult only if the water temperature exceeds 21°C, otherwise it remains in the larval form. There are no predators or other amphibians in the cave, so there is no explanation for this strange behavior. On the Galapagos Islands live two types of the bird with a curved beak. One type, which feeds on acorns, has a short beak, another that feeds on pines has a long beak. No doubt, there must have been, as their ancestor, a bird with an intermediate beak. Was he dying of hunger, not being able to shell acorns or pines?

Maybe it is the "chained" mutations in the genes that drive evolution? Recently, a gene was discovered that seems to serve only to speed up mutations³⁷. The *Pax6* gene identified in 1995, if taken from the mouse, makes eyes grow on the legs of the fly, and if it is completely missing, the entire head does not develop. This gene directs the functioning of others, and is very ancient, common to vertebrates and invertebrates, and even jellyfish. But it must cooperate with other genes. How so?



Fig. 5.11. (a) La rana dei Guinea, *Nectophrynoides occidentalis*, l'unico anfibio conosciuto che fa crescere i piccoli nell'utero, su questa foto è proprio incinta. (b) Axolotl di Messico (*Ambytona mexicum*) – una salamandra “fossile” che sfugge all'evoluzione: si riproduce anche nella fase larvale, se danneggiata è capace di rigenerare senza cicatrici gli arti, i polmoni, il midollo spinale e persino parti del cervello. (c) La coevoluzione: i “gancetti” tra due segmenti dell'ala dell'ape (vista al microscopio elettronico). FONTE: (a, b) Wikipedia, en.wikipedia.org; (c) Arizona State University, <https://aska.biologi.st.asu.edu/how-do-bees-fly>.

If the theory of evolution (and natural selection) could explain the disappearance of the gorilla's tail (it was no longer needed for humans), the mechanisms of concatenation or regulation of one gene

³⁷ E. PENNISI, *Supergenomes' drive evolution*, «Science» 357 (2017), p. 1083.

from the other (i.e. a relationship between the separate letters on the different pages of this book) is even harder to understand. We have not explained anything, but only shifted the question: change in the chicken or the egg?

The Catholic Church, in the words of John Paul II, recognized the concept of evolution as a scientific theory (i.e., based on experimentation) and not just a mere hypothesis. But the Church opposes the idea of man, as a "product" of biological evolution. St. John Paul II invites researchers to deepen the various aspects of evolution in order to give the right place to man with his *soul*.

An alternative concept to the theory of evolution is the *Intelligent Pro-ject*, which, however, lacks a solid methodology. It is assumed that the development of the world reflects the design of "a divine mind". In this sense, we return to the deistic ideas of eighteenth-century physicists who considered the world "a clock": once started, it no longer needs to be regulated. George Lemaître, the priest and cosmologist, proposed a third way³⁸:

The whole history of the world was not recorded in the first atom like a song on the phonograph record. All the matter in the world had to be present at the beginning, but history had to be written step by step.

The idea of "continuous creation" remains in line with Catholic theology. The world did not come out of the hands of the Creator as a final, perfect product. God, as the first cause, and we, as the second cause, participate day by day in creation. In his letter to the participants of the Congress on Evolution, St. John Paul II wrote:

On the basis of these considerations of my predecessor [Pius XII], a faith rightly understood in creation or a teaching rightly understood of evolution do not create obstacles: for evolution presupposes creation; creation stands in the light of evolution as an event that extends in time – as a "creatio contin-

³⁸ «The whole story of the world need not have been written down in the first quantum like a song on the disc of a phonograph. The whole matter of the world must have been present at the beginning, but the story it has to tell may be written step by step.» G. LEMAÎTRE, *The Beginning of the World from the Point of View of Quantum Theory*. «Nature» 127 (1931), p. 706, doi:10.1038/127706b0.

ua" – in which God becomes visible to the eyes of the believer as the Creator of heaven and earth.³⁹

As we have seen, the DNA of even the most primitive microbes is equipped for possible adversity: evolution seems extremely redundant, but it is "prophetic". Aristotle would have said: teleological. We will return to the question in Chapter VII, discussing the book by two physicists, Barrow and Tippler, entitled *The Anthropic Principle*.

5.14. Can we build an artificial life?

Yes, that is, not for the moment, but in a few centuries it will certainly be. Already today, we almost know how to synthesize amino acids from CO₂, ammoniac and water: we need a well-defined low temperature, precise concentrations and pressures, grains of cosmic dust with exact dimensions and edges, etc. With enzymes, physics techniques and powerful computers we can synthesize a few pieces of proteins.

We can also produce DNA by similarly precise procedures. We are not yet able to make a biological membrane to separate uric acid from the blood (i.e. an artificial kidney), but in the course of the 21st century we will.

With future computers and capacious data memories, with the virtual network of information exchanges, in a few centuries we will be able to make an artificial life. It takes intelligence, time (money) and the work of a billion brains. We will remake our lives! Will it be better than this?

Despite all the partial progress, the question remains: How has "stupid" inorganic matter managed to self-organize itself to do what humanity put together will need a billion years of person-year work? In genetics and in the theory of evolution, the epistemic situation is identical to the case of the quark in physics: we know how the world is made, but we don't know *why*.

With respect to the essential questions of physics, biology could almost, almost be explained by materialistic reasoning. But biology itself provides a skein of information that the human mind struggles to

³⁹ Address of John Paul II to the participants in the International Symposium on "Christian Faith and the Theory of Evolution." https://w2.vatican.va/content/john-paul-ii/it/speeches/1985/april/documents/hf_jp-ii_spe_19850426_studiosi-evoluzione.html.

manage. Was there really no *Logos* before? Or are we not yet able to see it? The teleologist⁴⁰ (not a theologian) would have said: *the purpose* of all this very complicated biology is the appearance of the most perfect organism in the material world - Man.

⁴⁰ The "teleologist", jokingly, is one who believes, like Aristotle (and the present author), in the teleological cause.

"Man and woman, He created them"

At the beginning of the previous chapter we discussed how the hypothesis of a pure chemical origin of life could obscure the beauty of the immense animated world. In a similar way, the acceptance of man's purely biological origin would have called into question all the richness of human culture. The main "stumbling block" in accepting the theory of evolution is the insistence of certain circles (who claim to be atheists) to confine human, unique mind in the biological world. So let's face the first question: is it true that man derives from an ape?

6.1. Does man derive from an ape?

One argument that is used in favour of a monkey-like man is the (apparent) genetic resemblance between the man and an ape. It is flaunted all around that man has 97.4% of the DNA identical to that of the chimpanzee. So is the difference between the two "species" really small?

One of the organisms with the best studied DNA is pufferfish, the delicacy of Japanese sushi, but with very poisonous meat. Its genome was deciphered in 2004, the second to be known after the human one¹. Because? The pufferfish, *Fugu rubripes*, has the smallest genome of all vertebrates, of "only" 365 million letters. Thanks to the "cheap" construction of its genome, pufferfish DNA contains few unused, i.e. redundant, genes². Man shares 75% of the genome with the pufferfish, despite the fact that we are separated by 400 million years of evolu-

¹ *Time Machine*, October 2002, <http://www.cinquantamila.it/storyTellerArticolo.php?storyId=0000000084712>.

² A few redundant genes could mean little "safety margin": in the case of changed living conditions, few chances of survival like the species.

tion. In addition, the study of the pufferfish genome has made it possible to identify almost 1000 previously unidentified human genes³.

Where do these similarities come from? From the common environment in which we live: the presence of oxygen for breathing, a metabolism using identical mechanisms, the ocean salinity, the visible solar light, etc. Thus, we also have DNA in common with flies and spiders. We share as much as 98.6% of our DNA with the chimpanzee. This genome is made up of 3.3 billion letters (nucleotide acids, A, G, C, T). But human DNA contains only about 30,000 sensible judgments (the "genes"), as they are called in genetics.

As Michele Gazzaniga points out (p. 49), "these 30,000 thousand genes occupy about 1.5% of the entire genome, since the remaining part of the genome has no coding functions. So most of the genome stands on its own with functions that are still unknown to us."

Quoting Michele Gazzaniga again, can the 1.4% of the genome that differs from the chimpanzee lead to such large differences? It is not just a numerical difference, but first and foremost functional and evolutionary. A dedicated study of the DNA sequences of 33.3 million bases of chimpanzee chromosome 22 with human chromosome 21 revealed "that 1.44% of the chromosome is made up of single-based subtractions as well as 68,000 insertions or subtractions. These differences are enough to generate changes in most proteins" (Gazzaniga, *Human*, p. 50). Not only a specific brain but totally different biology!

But it is not just a functional difference: it seems that, from the moment of the genetic separation between protohumans and chimpanzees, the two evolutionary lines have gone in divergent directions. "In addition, we demonstrated the presence of a different expansion in particular sub-families of retro-transpositions in the two orders of descent, suggesting a different influence of retro-transpositions in the evolution of humans and chimpanzees."⁴ The study authors conclude that the changes in the genome after *speciation* and their biological consequences seem much more complex than was initially assumed. A sentence to be repeated in all school books, also for children.

³ *Pufferfish DNA Yields Clues to Human Biology*, Joint Genome Institute, University of California, https://jgi.doe.gov/news_7_25_02/. Exact numbers can vary in different studies.

⁴ H. Watanabe et al., *DNA sequence and comparative analysis of chimpanzee chromosome 22*, «Nature» 429 (2004), pp. 382-348, citato da M.S. Gazzaniga, *Human*, p. 50.

Returning to the initial question – does man derive from the ape? – genetics answers: surely not! A completely casual similarity, not *causal*. Totally to be understood, yet.

6.2. A highly branched tree

Numerous chimpanzee behaviors, for example the ability to organize hunting in groups, or the ease in learning daily human activities, are other arguments put forward by the supporters of our close relationship with apes. Sentimental photos of orangutans with their young in their arms are shown, and complex social relationships within gorilla groups are invoked. Some monkeys stretch out their hands to ask for food, others cover their heads if they wish to be left alone, capuchins (*Cebus apella*) have a sense of injustice, chimpanzees harbor revenge and wage war with each other⁵. The biological ranking places us all together, men, monkeys, lemurs and tarsiers, in the order of "primates". All have five fingers and teeth suitable for the omnivorous diet. But what exactly are the relationships?

Humans and apes have common ancestors, but after separating they follow divergent evolutionary lines. "Le Scienze", the Italian version of "Scientific America", summarized these conclusions with a kind of family tree (see fig. 6.1).

A detail of this tree is that it highlights the "lateral" branches. *Homo sapiens* is placed on the main line of development, and other species diverged distinctly in a distant past: chimpanzees 6 million years ago, gorillas 9 million years ago, orangutans (which are often presented as particularly similar to us) - 16 million years ago. Since then, the lines of development have never crossed, intertwined, or mixed. Separation from other branches of primates occurred tens of millions ago: for example, with spider-monkeys 40 million years ago.

The development of the order of primates started immediately, together with other mammals. A recent discovery in China spotted a small mouse with a long tail (2013), climbing trees, the *Archigeomys achilles*. The fossil dates back to 55 million years ago, just 10 million

⁵ *Primates: 11 typically human behaviors*, Focus, 22/02/2018 <https://www.focus.en/environment/animals/behaviors-of-primates-typically-human>.

years after the disappearance of the dinosaurs. The *Archigeus* was probably a progenitor of today's tarsiers, i.e. small nocturnal monkeys.

Considering only the "natural" rhythms of evolution, i.e. the probability of DNA mutations and environmental variations, it is a slow very process. Therefore, it took tens of millions of years to form a "biological container" capable of embrace the richness of Man's psychic functions. The evolution of other primates, on the other hand, has followed different paths. What about the complex social behaviors of monkeys? They are necessary mechanisms for the life in groups, but they have nothing to do with the morality, reserved for men. But from the *Archigeus* (or another mammal, directly at the beginning of our family tree) to *Homo sapiens* the distance is still huge: an epoch.

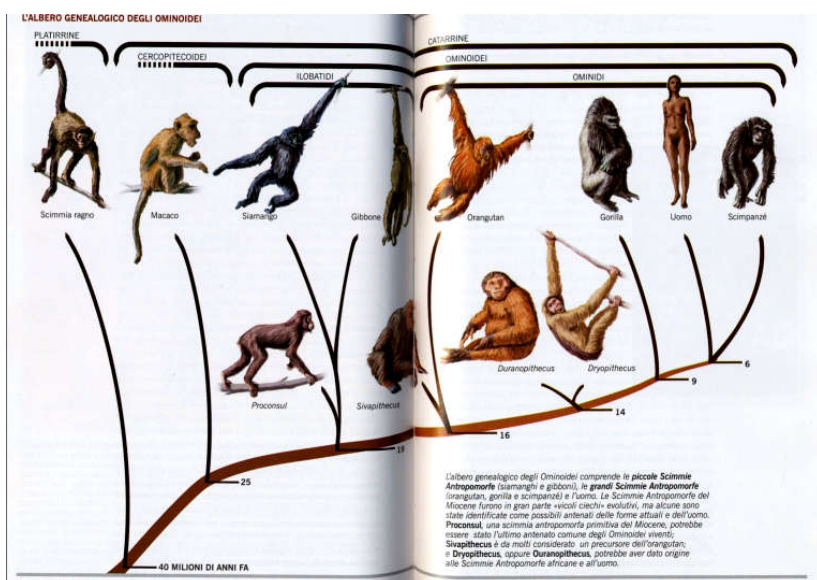


Fig. 6.1. The "genealogical" tree of primates, i.e. monkeys, anthropomorphic apes and man. The tree shows a continuity, which does not have to be necessarily valid. Important on this graph is the fact that orangutans, gorillas and chimpanzees diverged from the biological development line of *Homo* a long time ago (12, 9 and 6 million years respectively). SOURCE: "Le Scienze".

6.3. On two legs

A decisive step towards the formation of the genus *Homo* was the upright position of the body. It allows not only a better view of the surroundings, as in the case of marmots on guard. The permanent posi-

tion on two feet allows first of all to free the hands for an infinite number of functions, starting with that of dividing the food.

The oldest record of primates that have exploited locomotion in an upright position dates back to 3.7 million years ago. The footprints of a female *Australopithecus afarensis* were discovered in 1976 by the English researcher Mary Leakey in the volcanic tuff of Laetoli, in present-day Tanzania. Given that in parallel with the footprints of the fem, those of two other individuals were also found, perhaps it is the walk of a family unit, as the English version of Wikipedia writes.

Around the same time, a female skeleton of *Australopithecus afarensis*, called Lucy, was discovered in Ethiopia. The skeleton has characteristics favorable for bipedalism: the specific construction of the pelvis, the flat feet, the bones of the arms shorter than the legs (about halfway between the proportions of man and chimpanzee).

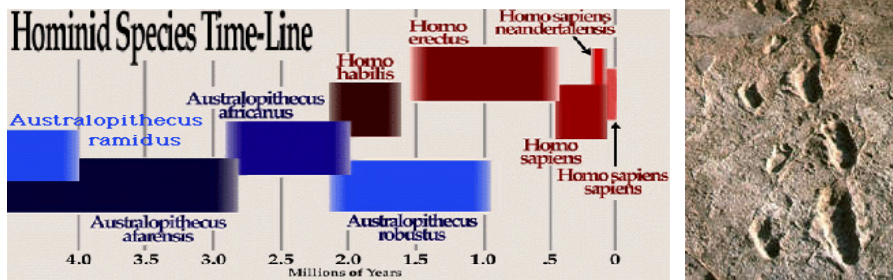


Fig. 6.2. (a) The lines of development of the first hominids, about 4 million years ago. Different forms of anthropomorphic *Australopithecus*, dating back to overlapping periods were discovered throughout Africa. It seems that evolution has "tried" numerous solutions, most of which have become extinct. Some species of *Australopithecus* already coexisted with early forms of *Homo*. (b) The first discovery of the footprints of bipedal hominids: the footprints of 3 individuals in the volcanic tuff at Laetoli, 1976. SOURCE: (a) <https://juanat.files.wordpress.com/2011/02/timeline.gif>; (b) *Hominid Fossil Repository*, University of Michigan, <http://projects.leadr.msu.edu/hominid-fossils/items/show/84>, accessed 14/05/2019.

Chimpanzees seem to have stopped in their evolution, since they have always occupied the same "ecological niche", the tropical forest. Man's ancestors went into the savannah. Simplifying a little, about 4 million years ago, the growth of a mountain barrier in the "vertical" direction, i.e. from north to south (the Ruwenzori range and other parallel ones) in central Africa, with peaks exceeding 5 thousand meters, changed the climate in the eastern part of the African continent. To the

west of the range the tropical forests still flourished, while to the east the savannah appeared, dry and covered with tall grass. The man's pro-parents in the savannah assumed the upright position.

Bipedalism and the liberation of the hands also made it possible to change the diet: from twigs and leaves (such as gorillas), which required strong teeth, to fruit (and possibly meat). In the skull the space for the brain increased; moreover, the blood flow previously necessary for digestion was directed from the belly to the head.

The appearance of *Australopithecus afarensis*, about 4 million years ago (see Fig. 6.2a) coincides with the geological changes of East Africa: the rise of the watershed chains and the formation of the Great Lakes. The question remains: was it climate change that forced evolution or was it the pre-programmed richness of "redundant" pre-human DNA that allowed Lucy's descendants to colonize the savannah? Or was it a fortuitous "coincidence"⁶? A hominid who "by chance" found himself in the right place, at the right evolutionary moment? Later, Lucy's descendants gained the ability to colonize almost the entire globe⁷. But in between, as always, progress, biological and mental, has taken other steps.

6.4. *Homo erectus*: the great walker

The body (and skull) size of australopithecines was still similar to that of today's chimpanzees. The shape of the skeleton also allowed four-legged running. There are no traces of the manufacture of tools or the use of fire by *Australopithecus*, whose diffusion remained limited to Africa (hence the name "southern hominid"). Between its appearance and the birth of *Homo sapiens*, 4 million years passed.

About halfway through that period, the first specimens of *Homo* appeared, with the shape of the skeleton decidedly suitable for locomotion in an upright position, the ability to get tools and to light fire (a million years ago). Evolution continued at a rapid pace: the brain improved, but also the skeleton.

⁶ In Polish I use a play of words: "zbieg" means both coincidence, and evading the prison. I say: "Evasion can be from Alcatraz, and the coin-cidence is called God's *pro-vidence*."

⁷ Obviously, writing "descendants" is still a mere conjecture: there is no direct evidence of kinship, but only temporal sequences of paleontological finds.

An article in the prestigious journal *Nature*⁸ a few years ago asked the question: "Why can't chimpanzees play baseball?" An experienced baseball player is capable of throwing the ball at a speed of almost 140 km/h. The throw uses different movements: of the torso, shoulder, arm, forearm and wrist in the final phase (see Fig. 6.3a). Having broad and muscular shoulders is decisive to become pitching champions in baseball. A movable shoulder blade, a robust pelvis, and a larger skull differentiate the genus *Homo* from *Australopithecus*. Why?

The almost complete skeleton of a boy dating back to 1.6 million years ago was found in Lake Turkana in Tanzania: he was not yet a modern man, although perfectly suited to standing and long walks. His height as an adult would be 180 cm. But to the skeleton, similar to that of *Homo sapiens*, an ape's head was still assembled, like Lucy's.

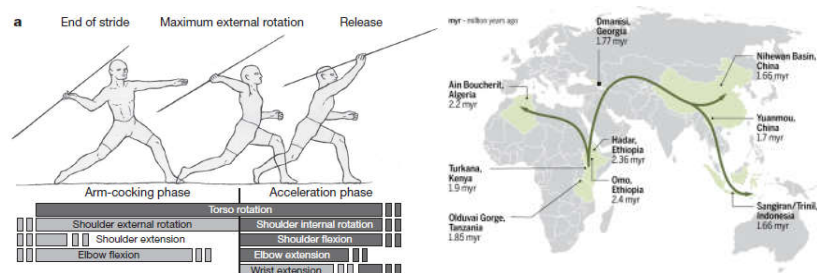


Fig. 6.3. The hunting capacity of the first species of *Homo* was determined by its physiognomy: a rolling basin, a wide shoulder and an extended arm. b) The sites of discovery of the remains of the first species of *Homo* (*erectus*, *habilis*, *ergaster*) and the migration routes of *Homo erectus* between 1-2 million years ago. SOURCE: «Nature», 498 (2013), pp. 483-486; G. GRULLÓN, «SCIENCE» 354 (2016), p. 958.

The cranial capacity of the "Turkana boy" was equal to half of *Homo sapiens*: space for the vocal organs appears in the skull, but the channels to connect them with the brain are still missing. The hominid was probably able to articulate various sounds, but did not yet use human language. Small steps of evolution, but no breakthrough.

The ability to throw stones and then, certainly starting from 300 thousand years ago, also specially prepared spears⁹ allowed *Homo* to

⁸ N.T. Roach *et al.*, *Elastic energy storage in the shoulder and the evolution of high-speed throwing in Homo*, «Nature» 498 (2013), pp. 483-486.

⁹ The remains of spears used by *Homo heidelbergensis*, dating back to 300 thousand years ago, were discovered in Germany and Africa.

become a migratory predator and be able to change environments according to the seasons and to explore new territories. Thus, within a few hundred thousand years, *Homo erectus* occupied the entire Afro-Euro-Asian mega-continent (see fig. 6.3b).¹⁰

In fact, the remains of the species *Homo erectus* dating back to about 1.8 million years ago were found on the "windowsill" of the Caucasus (in the caves of Dmanisi in Georgia); while those found in present-day China (*Homo pechinensis*) and in the Gran Dolina in the mountains of Castile-León in Spain date back to about 700 and 880 thousand years ago, respectively. Two million years ago, the appearance of the genus *Homo* began to diverge from orangutans and chimpanzees (see forensic reconstructions in Fig. 6.4).¹¹



Fig. 6.4. Forensic reconstructions of two primitive hominids and two species of *Homo* that biologically preceded *Homo sapiens sapiens*: *Ardipithecus rami-dus* (about 4.4 million years ago), *Australopithecus afarensis* (about 3.4 million years ago), *Homo habilis* (2.2-0.8 million years ago), the Neanderthal Man (400-40 thousand years ago). The dimensions are not exact: the cranial capacity of *Australopithecus* was about 1/3 of that of Neanderthals, while that of *Homo habilis* was just over half the size of the human brain (i.e. equal to the brain of a one-year-old child). SOURCE: CICERO MORAES.

Obviously, reconstructions based on skull fragments do not exhaust the possible individual variations. We do not even know to what extent the first pre-human species were different: in fact, they are called by particular names: *Homo* able, erected, worker (*habilis*, *erectus*, *ergaster*) or according to the geographical regions of the finds.

About 800 thousand years ago, the forms most similar to *Homo sapiens* appeared: the cranial capacity of Neanderthal Man reaches ours,

¹⁰ B.R. FENTON, *Homo Sapiens Direct Ancestors Migrated Out of Africa 2-million year ago*, <https://resonancescience.org/> (accesso 20/05/2019).

¹¹ CICERO MORAES, *Facial Reconstructions of Human Evolution*, http://www.cicero-moraes.com.br/doc/pt_br/Moraes/RFF_Evolucao.html (25/07/2018).

even if his stature was shorter (and more robust). Neanderthal man disappeared in Europe some 40 thousand years ago, after the arrival of the new species; the *Homo sapiens* also came from Central Africa, an abundant paradise of "all kinds of trees pleasant in appearance and good to eat".

6.5. The discovery of fire

Homo habilis was decisively distinguished from both *Australopithecus* and modern apes. In fact, the first traces of activities that characterize man date back to the *habilis*: he built huts (but storks also weave nests), used tools (but even the crow knows how to use a twig to extract ants from their nests), showed a certain aesthetic taste (but even the magpie thief likes shiny objects). Two important features of the genus *Homo*, in its pre-human species, were the use of fire and hunting with specially made weapons.

Research on the controlled use of fire is not easy: it is necessary to distinguish the ashes of specially lit hearths from random fires. It seems that *Homo erectus* knew how to use fire as early as a million years ago. In 2012, the results of physical and microscopic analyses of the deposits of the Wonderwerk Cave quarry in South Africa were published¹². The results are consistent with the permanent use of fire in the quarry; in particular, remains of burnt (and even unburned) bones have been found: see Fig. 6.5b. Primitive flint tools have also been found in the same layer (fig. 6.6c).

In the same year 2012, and again in South Africa (in Kathu Pan) the remains of split stone blades were discovered, which in all probability constituted the tip of spears for hunting large animals (see fig. 6.6b). The remains have been dated (with the fluorescence technique) to 464±47 thousand years ago. Compared to previous finds, this discovery takes us back to the first technological revolution of man: to about half a million years ago.

The documentation on the use of specially prepared tools already hundreds of thousands of years ago is extensive. As the authors of the

¹² F. BERNA *et al.* *Microstratigraphic evidence of in situ fire in the Acheulean strata of Wonderwerk Cave, Northern Cape province, South Africa*, «Proc. Natl. Acad. Sci. U.S.A.» 109 (2012), pp. 1215-1220.

2012 discovery write: "For about 780 thousand years, hominids had been killing large prey, as evidenced by traces of *in situ preparation* of complete fallow deer carcasses at Geshe Benot Ya'kov in Israel"¹³.

In the English town of Boxgrove, a scapula of a horse with a semi-circular perforation was found, from which it can be deduced that spear hunting was already practiced about 500 thousand years ago. The wooden spears dated about 400 thousand years ago were found together with the remains of horses slaughtered in Schöningen, Germany: they are similar to modern javelins, with the center of gravity placed at the front, and allowed a throw up to 70 meters away¹⁴. Flint points tied to a handle became frequent in the Middle Stone Age and Middle Paleolithic in Europe and Africa, some 300 thousand years ago.

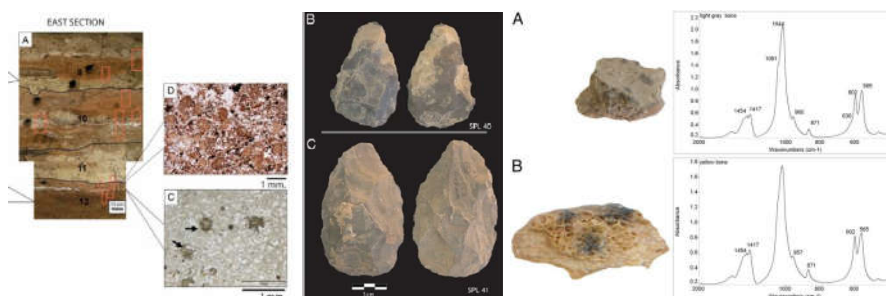


Fig. 6.5. (a) Layer No. 10 of the Wonderwerk Cave with microgranules of ash. (b) The stone axes of the same layer as the cave. (c) Two bone fragments: on top of a piece that was burned at 400° C, below the unburned bone; on the right the relative absorption spectra in the infrared. SOURCE: BERN *et al.*, «Proc. Natl. Acad. Sci. U.S.A.», 2012.

With the transition from *Australopithecus* to *Homo erectus*, two million years ago, a biological revolution took place: *Homo erectus* had a stature very similar to us. In the period between one million and half a million years ago (which corresponds roughly to the appearance of Neanderthal Man and previous similar species) a technological revolution took place: the invention of elaborate weapons and the discovery of fire.

¹³ J. WILKINS *et al.*, *Evidence for Early Hafted Hunting Technology*, «Science», 338 (2012), pp. 942-946.

¹⁴ https://en.wikipedia.org/wiki/Sch%C3%B6ningen_spears

Cooked (and protein) foods made it possible to reduce the jaws¹⁵, and consequently freed up space for the organs of vocal communication. The use of language, in turn, stimulated the development of the brain. All these changes, slowly, in spurts counted by the individual mutations, have prepared the biological structures to host intelligent thought. Again the question arises: were they random changes, guided by an "intelligent design", or the result of a direct creative action? By Whom?

In order to be able to speak of Man in the true sense of the word, *Homo sapiens sapiens*, we need to identify a cultural revolution: the birth of the intelligent thought. But first, let's go back to biology again.

6.6. Alone on the summit

Different interpretations of the family tree of *Homo sapiens* have important philosophical repercussions on our conception of ourselves in the world. Among the numerous diagrams on the internet, we chose the tree designed at the Smithsonian Institute of Natural History in Washington. This drawing contains some very interesting features.

First of all, the Smithsonian tree makes it clear that the large number of paleontological findings does not mean that man has all these relatives: most *australopithecines*, *paranthrops* or *ardipithecues* were "blind alleys" of evolution, rather separate and then extinct islands. At the top of the tree, after the narrow and twisted path with unknown roots, no a generic *Homo sapiens* is placed but a photo of a family: "You are here". It is also clear that we have closer relationships only with certain species of the genus *Homo*, starting from 2 million years ago, see fig. 6.6.

In particular, it is not yet clear whether the Neanderthal Man, who preceded *Homo sapiens* in Europe (and who became extinct when the latter began to prevail over Cro-Magnon Man), could "cross" with our ancestors. Undoubtedly, only *Homo sapiens* has left traces of its culture, which are identical to the west of the Euro-Asian continent (in Altamura in Spain) and to the east (in Indonesia).

¹⁵ Here we use a somewhat simplified narrative. In reality, the changes proceeded in parallel and it is not possible to establish cause and effect. Without a doubt, the point of arrival of these changes (or their purpose) is *Homo sapiens*, a creature completely different from previous forms, with its language, mind, work and intellectual capacities.

None of these cultural footprints are older than a hundred thousand years ago. “By coin-cidence” (see a note before in this chapter) the modern genetics dates back to 120 thousand years ago a milestone for the appearance of Man as we understand him: only one mother and one father for all individuals of *Homo sapiens* present today on the entire globe. Like in the Bible?

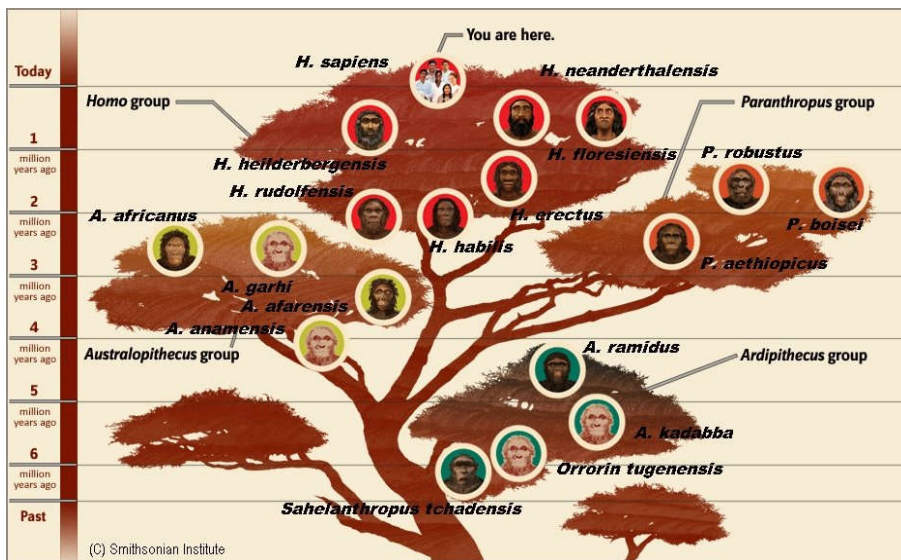


Fig. 6.6. Among the different representations of the family tree of *Homo sapiens* we have chosen the one on the internet pages of the Smithsonian Institute of Natural History in Washington, USA. This institute, with a clear Christian profile, does not put a "Homo" at the top of the tree, but a person with her family; other "relatives" are on the side branches, extinct. There is no reference to the possible similarities between "us" with Neanderthals, *Homo floresiensis*, etc. SOURCE: Smithsonian Institute of Natural History.

6.7. Mitochondrial Eve

The question of whether Adam and Eve, the first parents of all mankind, existed is of essential importance if we are to take the Christian faith "seriously." In the First Letter to the Corinthians¹⁶, St. Paul,

¹⁶ 1 Cor, 15, 22-22 and 45-47, Edition CEI2008

speaking of the Resurrection, makes a comparison between Adam and Jesus¹⁷:

Now, however, Christ has risen from the dead, the mercy of those who have died. For if death came through a man, the resurrection of the dead will also come through a man. For as in Adam all die, so in Christ all will receive life.

For it is written that the first man, Adam, became a living being, but the last Adam became a life-giving spirit. There was not first the spiritual body, but the animal body, and then the spiritual. The first man, taken from the earth, is made of earth; the second man comes from heaven.

If our progenitors, Adam and Eve, were only a parable, so maybe we should agree with intellectuals like the French writer Ernest Renan who searched in Christ just a concrete person, lived in particular social environment, in a precise historical moment and not the *Redeemer*? At this point, do the Passion and Resurrection also lose their supernatural meaning? Given the basic importance of the argument on the existence of Adam, we must agree with Vittorio Messori, probably the most important contemporary Christian writer, that if totally convincing scientific proofs would replace the faith, there would be no space for our free will in searching the personal Salvation. In other words, we would all march directly to the paradise, in the same uniforms, tailored by science. For me, as a scientists: a horror! With this essential caveat, let's move on to the recent discoveries of genetics.

As we have already mentioned, the human DNA code contains something like 3.3 billion letters, and it was only deciphered in the early 21st century thanks to powerful computers. DNA encodes all the characteristics of a species and of an individual. But sexual reproduction, thanks to which there are practically no two identical individuals, is also subject to transcription errors: many of these errors (such as a foot with six fingers) are not serious. But metabolic processes - the conversion of nutrients into energy are essential for the very existence of a cell.

The energy production cycles are carried out in specialized organelles, called mitochondria (a kind of electrical power unit of each cell). The importance of these processes requires that the genes gov-

¹⁷ See also BENEDICT XVI, *Adam and Christ: From (Original) Sin to Freedom*, General Audience, 3/12/2008.

erning them are not transmitted with the rest of DNA, subject to possible transcription errors, but separately, in mitochondria. For this reason, mitochondrial DNA is inherited directly (and exclusively) from the mother through the egg cell. A mother transmits this DNA directly to her daughter (and son) and the daughter - to her granddaughter, and so on.

Human mitochondrial DNA contains only 16.5 thousand nucleotide base pairs and encodes only 37 proteins. It was deciphered in 1986. It has been discovered that mitochondrial DNA in *Homo sapiens* is subject to fairly rare variations, on average every 8-11 thousand years. This "molecular clock" and comparison of the DNA of different men on all continents leads to the conclusion that about 120-140 thousand years ago all men had the same mitochondrial DNA. Since mitochondrial DNA is transmitted through the mother, the expression "mitochondrial Eve" was coined to define the hypothetical common mother of all men. But this mother may have been (must/ should/ should have been/ was) real, not hypothetical - 120 thousand years ago.

A simplified version of the relationship through mitochondrial DNA and the map of migration directions can be seen in Fig. 6.7. Between the mitochondrial Eve and its more distant descendants genetically there are only 5 "steps", while main genetic groups (haplotypes) are quite few.

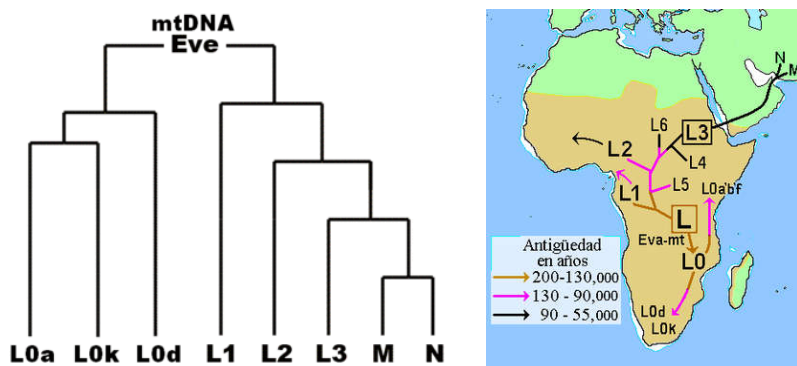


Fig. 6.7. The Wikipedia entry "Eve_mitochondrial" reports a simplified graph of the close relationship between all currently living men (significant samples of different "races" have been studied) with a hypothetical woman, the only mother of all of us. On the right are indicated the directions of the movements of the descendants of this mother, starting from East Africa. SOURCE: Wikipedia.

As this result is of essential importance let's state it again more precisely: "modern genetic studies *point out* towards an identical mitochondrial DNA some 120 thousand years, for all currently living individuals of *Homo sapiens*". The exact term is "the most recent common (female) ancestor". As active, experimental physicist I stress "point out". Like all the cosmology, astronomy and physics *point out* towards a Big Bang. Not "prove", in terms of Galileo's experiments on stones falling from the Tower in Pisa, but *indicate*, up to the best currently available methodology.

Recent very extensive comparisons¹⁸ (see fig. 6.8) between different populations of Europe, Asia, Africa, gave a more complex picture, but always date the same maternal genome to about 200 thousand years ago, and always locate it in the eastern part of Central Africa. In this figure, the detailed differences in DNA between the common mother and the inhabitants of Western Europe are thirteen. The entire family tree of all humanity has, on this scientific graph, a unique starting "point" – a single, common, female ancestor.

An objection which is frequently risen is that the same genetic mutation, leading to a common mitochondrial DNA could have happened in more than one individual. I respond with a joke: while a mathematician brings with him a bomb on board while flying an aeroplane? It is clear: the probability of finding a bomb on board is one over million, and of two bombs practically null.

For more recent times (and populations in closer geographic relations) the precision of similar comparisons is better and it is also possible to give the limits of uncertainty. For example, the genome of *haplogroup* M1 appeared in Europe 36.8 ± 7.1 thousand years ago. This date corresponds, within a certain margin of error, to the age of human rests (about 43 thousand years) found in Cro-Magnon. The Mediterranean haplogroup separated 23.4 ± 5.6 thousand years ago and the population of Sardinia shows a common relationship back to 7.7 ± 3.1 thousand years ago.

¹⁸ A. OLIVIERI *et al.*, *The mtDNA legacy of the Levantine early Upper Paleolithic in Africa*, «Science», 314 (2006), pp. 1767-1770.

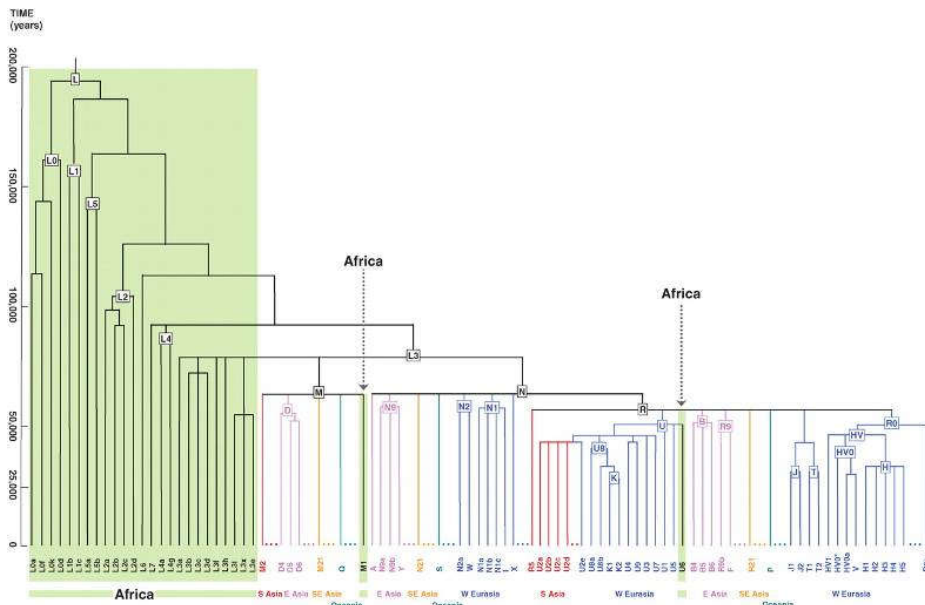


Fig. 6.8. A recent study of the family tree of the whole of humanity (from Africa and Oceania to Western Europe) dates the common mother to about 200 thousand years ago. Different studies agree on the existence of a common progenitor, from which we are separated by 9-12 genetic "steps". SOURCE: A. OLIVIERI *et al.*, 'Science'.

The discovery of mitochondrial DNA dating back to the same ancestor was completely unexpected. Its cultural importance is comparable to the Copernican revolution. Unfortunately, the news did not find adequate cultural resonance: science did confess any self-criticism, nor was Faith strengthened.

6.8. A common Adam

The genetic content of human mitochondria is quite simple. It remains very complicated to decipher the male's assets. It was only in 2013 that the Y chromosome (the one that is inherited only through the father) was studied in detail. It is much larger than mitochondrial DNA: it contains a sequence of 65 million nucleotide base pairs. The study compared males: Bushmen from Namibia, Pygmies from Congo and Gabon, Berbers from Algeria, Pashtuns from Pakistan, Cambodians, and Yakut from Siberia.

shown in Figure 6.10. Clearly, also genetic studies are subject to the same statistical uncertainties as the measurements in physics. But the importance of the study by Poznik *et al.* lies in the evidence that the appearance of the first man and the first woman coincide with the genome that we all carry.

Fig. 3. Similarity of T_{MRCA} does not imply equivalent N_e of males and females. The T_{MRCA} for a given locus is drawn from a predata (i.e., prior) distribution that is a function of N_e , generation time, sample size, and demographic history. Consider the distribution of possible T_{MRCA} s for a set of 100 uniparental chromosomes. Although the Mbuti mtDNA N_e is twice as large as that of the Baka Y chromosome, the corresponding predata T_{MRCA} distributions overlap considerably.

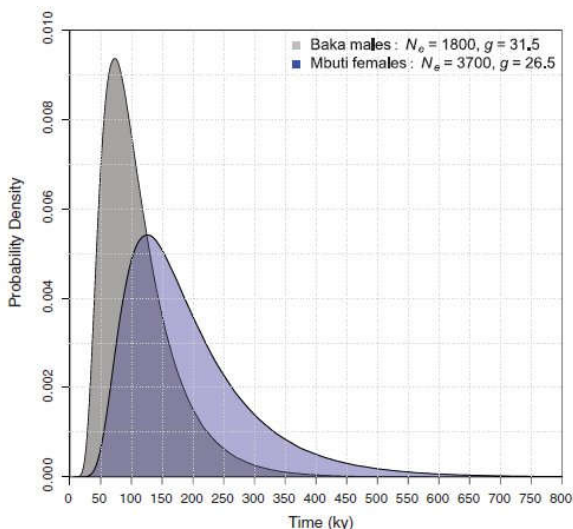


Fig. 6.10. The similarity of the date of the last common ancestor, for two native peoples of Africa: the date was obtained from the study of the Y chromosome for the male ancestor "Adam" and from the mitochondrial DNA for the female ancestor "Eve". Note the characteristic statistical spread for analyses with a limited number of data (i.e. Poisson distribution). Nevertheless, the two curves overlap. SOURCE: D. POZNIK *et al.*, «Science», 2013.

The rapidity with which the new genome appeared, the very location and the concomitance between the male and the female lead to the "temptation to call her Eve", as the authors of the exhibition on *Homo sapiens* presented a few years ago at the Science Museum in Trento²⁰ wrote. But the authors themselves put their hands forward, writing that "that common mitochondrial DNA matrix must have belonged to a woman from the African 'founding group' from which all *H. sapiens* originated."

²⁰ L.L. CAVALLO SFORZA, T. PIEVANI, *Homo sapiens. The great story of human diversity*. Scientific exhibition, Science Museum Trento 2012, Catalogue, Codice Edizioni, p. 30.

Perhaps this is not really the case: genetics teaches that a mutation always belongs to a single individual. In the same individual, in the combination of genes, in their transposition and substitution, more than one mutation can be found: in an instant (in "a breath") a whole series of concatenated changes can occur, which lead to a completely different quality. The biological part in *Homo sapiens* is no longer decisive.

It should be emphasized once again that genetics indicates the same time (within the limits of statistical uncertainty) for the appearance of the common male (Adam) and female (Eve) ancestor for the entire human genre. As in the case of physics and the Big Bang, so too with genetics and the first parents: the Bible is not a science book, on the other hand science is not used to comment on the Bible. The important aspect is that, in the mind of the same person, Sacred Scripture and Nature *are not* contradictory. So far, everything confirms Galileo's words that both the Bible and Nature were dictated by God.

6.9. Self-awareness

The monkey recognizes his own face in the mirror, because it conforms to the images of his peers. But if a stain is drawn on its forehead, the monkey tries to clean the glass, not its own face: the chimpanzee is not aware of itself ("itself", not "himself").

Nick Lane, the scientist already cited for his exceptional studies of biology, on the subject of the roots of the human mind, begins by quoting Pope John Paul II's speech to the Pontifical Academy of Sciences: "The human mind was forever beyond the domain of science."

Today, in the same way that *we suppose* we can explain the masses of quarks in physics and the "spontaneous" self-aggregation of amino acids in DNA, we would also like to set up a self-organization of neurons to bring the human self-consciousness. Nick Lane is aware of this assumption and puts "his hands forward": "This is not a book about religion, and I don't want to attack anyone's religious beliefs"²¹. He begins the discussion of conscience by quoting Pope John Paul II:

²¹ N. LANE, *op. cit.*, p. 225..

The human mind, he said, was forever beyond the domain of science. 'Consequently, theories of evolution which, according to the philosophy which inspires them, consider the spirit as emerging from the forces of living matter or as a mere epiphenomenon of this matter, are incompatible with the truth of man. They are also incapable of establishing the dignity of the person.' Inner experience and self-awareness, he said, all the metaphysical apparatus through which we communicate with God, are removed from the objective measurements of science, re-entering the realms of philosophy and theology.

Then, Nick Lane also expresses his personal caution about treating the human mind as a purely material entity (pp. 226-7):

I am quoting the pope because I think that what he says goes beyond religion, to the heart of man's conception of himself. Even those who are not religious can feel that their spirit is somehow immaterial, something unique, and somehow 'beyond science'. The pope's position seems to me defensible, since we do not know how 'mere matter' generates the immateriality perceived by the mind; In fact, we don't even know what mere matter really is, or why matter exists instead of total nothingness (a question somewhat analogous to that of why consciousness exists, rather than an unconscious processing of information). [provisional quotation, being translation from Italian]

We are quoting an evolutionary biologist, to point out that the question of consciousness or, speaking as a believer, of the human soul, extends beyond the domain of the (material) sciences. Important contributions to this conclusion come also from neurology.

Paleontological and archaeological studies show that after 2 million years of biologically "preparative" forms, suddenly, about a hundred thousand years ago, culture exploded (we will talk about it later), the manufacture of complex objects (needles, flutes), intentional burials were carried out, etc. *Homo* becomes a *mentally* creative creature. This occurs with little growth in cranial capacity as compared to Neanderthals.

A useful comparison to understand this explosion of thought is the concept of critical mass, born with nuclear physics. A pile of uranium (isotope ²³⁵U) on the table is a harmless metal, not even very radioactive. But add another spoon to this, and the battery becomes an atomic bomb: it explodes in a fraction of a second, with a force that exceeds millions of times the same amount of dynamite. Let's talk about critical mass: uranium decays (splits) and emits two or three neutrons. If a neutron is captured by another uranium nucleus, it causes a new split. Till the pile is not too large, neutrons can escape from the volume of

uranium. Once the critical mass is exceeded, the amount of neutrons that do not escape is such as to cause the explosion to occur.

In various fields of physics, computer science, genetics, etc., we come up against the barrier of complexity: a computer, adding a program, suddenly wakes up; two fragments of DNA, even distant ones, can interact functioning as a single gene, ten electrons in the neon atom repel and attract each other. Sometimes the number of links between elements (electrons, genes, etc.) becomes too large to be managed (and monitored). But in all these systems, the interaction takes place between pairs of elements. In the human brain, the interaction is much, much more complex.

We can understand it with a simple graph. In biology, ecology, demography, etc., many phenomena are governed by *exponential* growth. If a pair of rabbits (i.e. two of them) hatches four, in a short time the whole continent will be infested with these rodents (it happened in Australia). In figure 6.11a we compare the exponential growth with the number of *combinations* of a given *number n* of elements with the defined order: the number of combinations *explodes* beyond the graph already for 8 neurons. We don't know how the brain works, but the comparison is very instructive: every mental operation requires the activation of many neurons in different combinations. This is much more than a simple exponential growth: an explosion.

The connections between neurons in the brain do not happen one by one: to express a thought, the whole "avalanche" of electrical signals is unleashed in various parts of the brain. The connections involve two, three, four neurons, and so on. Then, the electrical signal propagates with a well-defined sequence, which can also vary according to "a thought in the head": see in fig. 6.11b the series of signals ordered in time and space in different parts of the cerebral cortex after reading a word.

But the belief that an individual's brain is just a tangle of electrical wires or a human *personality* remains a private opinion. Two my colleagues (a physicist and a theologian) write as follows²²: "Man has another dimension received from the Creator, which binds them in a certain sense: he is *nishmat-hajjim*, living conscience, self-awareness,

²² M. SZETELA, G. OSIŃSKI, *The concept of "dialogical soul" by Joseph Ratzinger against the latest concepts of neurosciences*, «Scientia et Fides», 5 (2017), pp. 199-215.

the ability to distinguish good from evil, the freedom of moral choice." Another colleague, from the same corridor of the University, also a physicist and a "guru" of neurology, while admitting that the brain is the most complex structure in the universe, writes in the same journal: "Consciousness is not something that can be received, but a process that depends on the neuro-dynamics of the brain, when some parts of the brain comment on the states of the other parts".²³ In other words: a simple "tangle" of electrical cables, which has organized itself on its own...

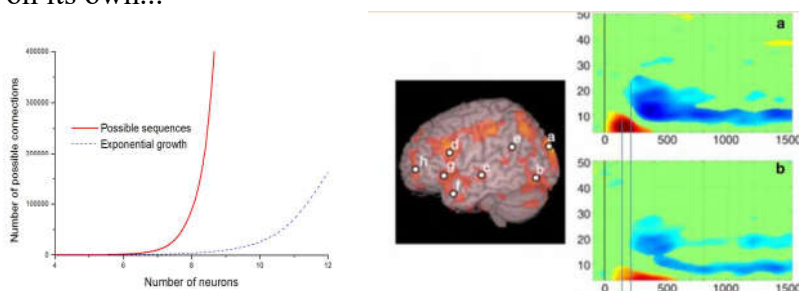


Fig. 6.11. (a) The amount of possible signal paths in a network of $n=8$ cells grows vertically (like the factor number $n!$), red curve. (b) The sequence and location in the brain of signals when reading a word. "In addition, the path of these signals is interesting, as the first signal at about 150 ms is a *gamma* signal (35-40 Hz), the second at about 200 ms – an *alpha* signal, and the next at about 300 ms again a *gamma*. The cortex network involved in the reading process is very complex, and *requires a spatio-temporal interplay of the different dynamic interactions*." ²⁴SOURCE: GK, KRISTINE PAMMER, «Frontiers in Human Neuroscience», 2014, with personal thanks.

We have several emotions in common with animals: the defense of the territory, the pleasure of good food, the maternal instinct. But human self-knowledge produces *feelings* that have no parallel in the animal world, such as modesty (it is not *shame* that comes after the fact but a *preventive* feeling), anticipatory anxiety (not fear with danger already in sight, nor regret after loss), sharing pain, altruism, etc. Many mammals have tear conduct, but only man cries to express his sad-

²³ W. DUCH, *Why minds cannot be received, but are created by brains*, «Scientia et Fides», 5 (2017), pp. 171-198.

²⁴ «The cortical networks involved in reading are highly complex, requiring a sophisticated interplay of temporally and spatially dynamic interactions.» Kristine Pammer, *Temporal sampling in vision and the implications for dyslexia*, «Frontiers in Human Neuroscience», 7 (2014), pp. 933.

ness, only man blushes because of shame. Michele Gazzaniga speaks of "an inner moral compass". We are capable of processing consciousness not only of ourselves, but also of things far beyond the present moment and of our ego. In a certain sense, man is distinguished from animals because he devotes himself to things that seem (locally and materially) useless. Art is a good (and universal) example of this.

If desired, any complex phenomenon can be simplified and reduced to the pure material dimension. But in this way our mind deprives itself of cognitive amazement, which is one of the most surprising characteristics of man. The aforementioned world-renowned neurologist Michele Gazzaniga concludes his book *Human. What makes us unique*: "That's enough! I go out to take care of my vineyard. My Pinot grape will soon produce excellent wine. I'm really glad I'm not a chimpanzee."

6.10. Culture: a decisive experience

Art is one of the most striking and representative common denominators of our "species". Already forty thousand years ago man used body ornaments, painted animals on the walls of caves, played the flute around the hearth. The documentation is abundant; the oldest date back to almost a hundred thousand years ago. The authors of the exhibition "Homo sapiens" write²⁵:

Around 45-40,000 years ago we no longer become only anatomically but also mentally modern. It is the flowering of an intelligence that has become symbolic and capable of abstraction: extraordinary cave paintings, immediately animated both by realistic hunting scenes and by stylized and symbolic figures; exquisite bone-carved artworks, sophisticated ritual burials; body ornaments, jewelry and embellishments; the first musical instruments; new techniques of stone working, first of the Aurignacian type, then rapidly advancing and differentiating into distinct regional cultures, the construction of more complex shelters, even in open spaces; perhaps even the first lunar calendars around 32,000 years ago.

Michele Gazzaniga, director of the Institute of Neuroscience at California, adds: "Art is one of the human universals. All cultures have

²⁵ L. L. CAVALLI SFORZA and T. PIEVANI, *op. cit.*, p. 58.

some form of it, whether it is painting, dance, stories, songs or other forms."²⁶

Many, if not all, limestone caves on the southwestern belt of France (and in Spain) are decorated with images of animals (bison, horses, deer), see drawings from Cantabrian, Altamira in fig. 6.14. The images were made using complicated techniques, using refined mineral dyes, which have allowed them to be preserved to this day. The paintings show not only a strong capacity for observation, but also reflect the desire to leave a testimony. Most of the European continent (apart from the very South-West area) at that time was covered by ice, and the caveman felt a constant threat to his existence. The paintings in the caves are his "*Non omnis moriar*".



Fig. 6.12. The cave paintings, about 15 thousand years ago, at the limestone quarries in Altamira on the north coast of Spain. Similar decorations, dating back to the period between 32 and 11 thousand years ago, have been found in many locations

in Spain and South-West France (Lascaux, Pech Merle, Chauvet, Roc-aux-Sorciers), where *Homo Cro-Magnon* found refuge during Ice Age. PHOTO: M.KARWASZ, 2018.

The sudden explosion of art forty thousand years ago is attributed by neuropsychologists to some genetic change. "Something has changed in our brains that has increased previous creative abilities, something unique to *Homo sapiens*," writes the neurosurgeon²⁷. Without a doubt, all the evidence of artistic creativity and spiritual beliefs belong only to our "species", the descendants of mitochondrial Eve, and Adam.

And in fact, the first "useless" artifacts date back to almost 100 thousand years ago, and were found there, on the borders of South Africa, in the cave of Blombos, beyond which there is only the ocean. Someone 85 thousand years ago – out of boredom or a sense of beauty

²⁶ M. S. GAZZANIGA, *op. cit.*, p. 258.

²⁷ *Ibid.*, p. 270.

or to make a technical drawing? – engraved crossed grooves on a piece of soft ochre, Fig. 6.13a.

Someone else, 40 thousand years ago, in today's Kenya, marked 28 vertical lines on the tooth of an elephant, connecting them with a horizontal line. Did it count for anything? And who? A woman in a cave? A real lunar calendar, not only with the phases of the Moon but also with its position, dates back to 32 thousand years ago and was found in present-day France (Aurignazan culture, fig. 6.13b).

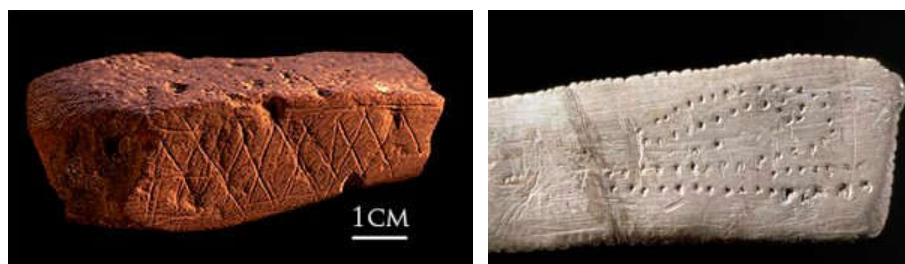


Fig. 6.13. (a) A piece of ochre, with a geometric pattern, dating back to 85,000 years ago, from the cave of Blombos Cave in South Africa, probably the oldest testimony of the intellectual identity of the genus *Homo sapiens*: today, children make similar drawings in notebooks, when they are bored at school. (b) A bone, from present-day France and dating back to about 32,000 years ago, with a series of semilunar and round engravings, which in 1970 was interpreted by Alexander Marshack²⁸ as the first evidence of a lunar calendar. SOURCE: Wikipedia; Peabody Museum of Archaeology and Ethnology at Harvard University.

Today we do not know how to attribute the meaning and/or technical use to so many artifacts left by Paleolithic man (see fig. 6.14a). The first portrait of a female statue, with a horn in her hand (the Venus of Laussel), dates back to 25,000 years ago²⁹, the artistic paradigm widespread throughout Europe in the form of baked ceramic statuettes (the Venus of Dolní Věstonice) for 30 thousand years (the Venus of Hohle Fels in ivory dates back to something like 40,000 years ago, while the already stylized figurines, such as the Venus of Monruz, about 11,000 years ago). The list not of artifacts, but of real works of

²⁸ A. MARSHACK, *Notation dans les gravures du paléolithique supérieur*, Publications de l'institut de Préhistoire de l'Université de Bordeaux. Mémoire No. 8, Bordeaux, Imprimeries Delmas, 1970. Vedi reed: <https://sservi.nasa.gov/articles/oldest-lunar-calendars/>.

²⁹ Venus de Laussel, https://fr.wikipedia.org/wiki/V%C3%A9nus_de_Laussel

art³⁰, such as sculptures (and images) of horse heads or bison licking insect bites, are countless: it was not a pastime, but a real need of the man of the remote Paleolithic to express his individual talent.



Fig. 6.14. (a) The artifacts (above the working of the bone) of Paleozoic man surprise us with their diversity, meticulous workmanship, rich ornamentation and (partially unknown) uses: the cut-out teeth of carnivores served, perhaps, as amulets; the plates decorated with animal motifs perhaps as pendants; while the long perforated bone as a flute³¹. (b) The paintings from the Sulawesi cavern in Indonesia: the stencil of the hand dates back to 40 thousand years ago, the drawing of the pig existing at that time - to 35,5 to years ago. SOURCE: D. VIALOU, Gallimard, 1996; M. AUBERT *et al.*, «Nature» 2014.

And not only in Europe (and Africa) do we find surprising cultural testimonies of *Homo sapiens*. Recently (2014), at the other end of the Euro-Asian continent, in present-day Indonesia,³² some cave paintings were found that look like copies of those in France³³: handprints and "photos" of hunting scenes, this time not of bison but of a type of pig that is now extinct (i.e. hunted too effectively, like the mammoth in Europe and Siberia).

The artistic style has changed over the millennia: not because of globalization, but on the basis of personal research into new ways of expression. Not only the great artists, but also, probably ordinary people try to tell us something through rock graffiti. In Val Camonica the

³⁰ Stone Age Art, https://en.wikipedia.org/wiki/List_of_Stone_Age_art

³¹ D. VIALOU, *Au cœur de la préhistoire. Hunters and artists*. Gallimard, Paris 1996, pp. 26-27.

³² M. AUBERT *et al.* *Pleistocene cave art from Sulawesi, Indonesia*, «Nature», 514 (2014), p. 223.

³³ Prehistoric art, https://fr.wikipedia.org/wiki/Art_pr%C3%A9historique.

drawings on the rocks (external, i.e. exposed to rain and wind) resemble modern graphic symbols. The doors of a tomb in Sicily four thousand years ago were decorated with a completely abstract relief; a washbasin more than three thousand years old has a decorated support, stylized to a female torso, which seems completely useless. The desire for beauty and the abstract mental connections reproduced in Neolithic artifacts surprise even our modern tastes.

What caused the transition from the realist representation of the Paleolithic to the abstract art of the Neolithic? A neuropsychologist would have answered: "the evolution of structures in the brain"; a climatologist instead: "the change in environmental conditions"; while a sociologist: "the different social position of the artist".



Fig. 6.15. Illustration does not serve to reflect the object or person but to present the image (i.e. an idea) on it, or another concept that the artist wants to convey. Some examples of the abstract art of prehistory: a) a proud Neolithic warrior in Val Camonica; b) a washbasin with a support in the shape of a female torso by Thapsos, XV-IX century BC, Museum of Syracuse. PHOTO: MK, 2003.

The question is analogous to these: why did Eduard Monet abandon the realistic (and profitable) paintings of the streets of Paris and choose a very controversial style of colored spots, called impressionism? Or, why did Picasso paint first in brown and then in blue? The fact is that for a hundred thousand years the artifacts of *Homo* have surprised us with their (i.e. our) creativity. And no trace of creativity dates back to any pre-human forms, with the caesura of a hundred thousand years ago.

But it is not the artifacts of the Paleolithic, but *our common* sense of beauty, truth, honesty that unites us. Surely, we humans are different from all other living beings. And also our intellect, sometimes anti-rational when difficult but morally right choices have to be made. The intellect (and the image), which aims at the most distant stars and

at the dawn of humanity itself, differentiates us from the "brutes". Aristotle wrote in *De anima*:

As regards thought, since it is different from sensation and seems to include imagination on the one hand, and intellectual apprehension on the other, after dealing with imagination, we must also speak of apprehension. If, then, imagination is that by which we say that an "appearance" is produced in us, and not if we say something by a metaphorical use of "imagination," it is one of the faculties or habits by which we judge and are in the true or the false. Such faculties and habits are sensation, opinion, science, and intellect.³⁴

6.11. The Tower of Babel: a linguistic reality

The story of the Tower of Babel should be another biblical "fairy tale". "It is, quite simply, a *naïve* explanation of the diversity of languages, nothing to do with the real facts. Strange constructions, called 'ziggurats', have been found in Mesopotamia, and the biblical writer let his imagination run wild." The Internet is full of such fanciful comments: in the footnote we mention some of them³⁵.

Is there any kinship between the languages of the Eurasian continent? Already at the beginning of the nineteenth century an "Indo-European" stock was identified, but several languages, including Albanian, Basque, Georgian, do not belong to this family. Traveling around the world, one realizes that some basic words, for example "mamma", are identical, in Polish, Italian and Korean (with small nuances of pronunciation). This idea has been studied in detail in recent years by an interdisciplinary group consisting of a linguist, a biologist, a psychologist and a computer scientist, from England, the United States and New Zealand³⁶.

³⁴ ARISTOTLE, *De anima*, trans. G. Movia, Bompiani, Milan, 2014, 427a, 27 - 428a, 5.

³⁵ "Perhaps it is a blessing because it allows us to avoid another curse, namely universal imperialism and also overpopulation, that is, the desire to keep the whole population in a single region and oblige them to participate in a 'single enterprise', that is, the construction of a single empire, to participate in a single political project." We do not report internet addresses of these phrases because they are not very sensible.

³⁶ M. PAGEL *et al.*, *Untraconserved words point to deep language ancestry cross Eurasia*, Proc. Natl. Acad. Sci. USA, 110 (2013) p. 8471.

The research group had analyzed similar words, of ancient root, in different languages, such as *brother* in English, *frère* in French, *fratello* in Italian, (*brat* in Polish) looking for relatives³⁷. 21 languages belonging to 7 distinct families were compared, including the languages of the Eskimos, the peoples of the mountains of Asia (Altai) and the remote Kamchatka Peninsula. Of 3800 proto-words, 188 similar ones were chosen and the family tree was reconstructed, using the statistical procedures also used in the studies of the genetic heritage.

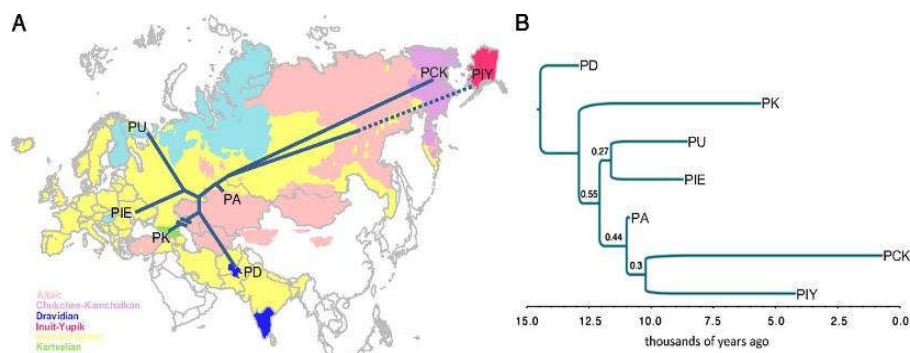


Fig. 6.16. The reconstruction of the family tree of seven different groups of languages of the entire Euro-Asian continent: Altaic, Kamchatka, Dravidian, Eskimo, Indo-European, Cartellean, Uralic. The Dravian language separated first, about 14,500 years ago, that of the Caucasus Mountains (Cartvelian) about 12,500 years ago. The Indo-European languages are the most "related" to Finno-Ugric. SOURCE: PNAS

Obviously, the limited number of words that have been preserved in common produces a statistical error bar. But the result is resounding: all the languages of the Euro-Asian pancontinent date back to the same stock, dating back to about 14.5 thousand years ago. The geographical center of the common derivation (always reconstructed with the methods used in genetics) can be located in ancient Mesopotamia: right there where the ziggurats were built, the tower of Babel in Bruegel's painting (fig. 6.16a).

As in the case of the creation of matter and Man, once again, modern scientific research, interdisciplinary, rigorous and mathematical,

³⁷ «The English word *brother* and the French *frère* are related to the Sanskrit *bhrātr* and the Latin *frāter*, suggesting that words as mere sounds can remain associated with the same meaning for millennia. But how far back in time can traces of a word's genealogical history persist, and can we predict which words are likely to show deep ancestry?»

confirms (or, rather, does not contradict) the biblical "story". On the other hand, why would the ancient scribe have invented things? Galileo defined the Bible as the book written under the inspiration of the Holy Spirit.

6.12. The desire for science

Modern Man or in short Man is distinguished from Neanderthal Man, *Homo ergaster*, *Homo pekinensis*, etc., not only for the creation of works of art, but also for the irrepressible desire to know, both useful things for hunting and subsistence as well as more generally all the phenomena of the whole world.



Fig. 6.17. (a) Are the remains of ziggurats in Mesopotamia evidence of the Tower of Babel (here Breughel's painting, on display in Vienna) or of ancient astronomical observers? (b) The megalithic complex of Hagar Qim in Malta, dating back to about 5.5 thousand years ago, was probably a temple, but also an astronomical calendar. PHOTO: M. KARWASZ, 2018.

Already in fig. 6.13 we have seen a piece of bone from about 30 thousand years ago with a series of signs that seem to be a lunar calendar. On the other hand, a calendar of 12 months of 30 days, and the subdivision of time into 12 hours and 60 minutes, not at all corresponding to a "natural" system, i.e. decimal, was developed years ago by the Sumerians and certainly must have had pre-existing bases. The only problem is that rarely fragile bones can be preserved in the soil for millennia.

Monumental calendars, such as Stonehenge, are scattered in different places. It seems that they were used to determine the summer solstice, that is, the longest day of the year. But at different latitudes the

position of the Sun on the horizon is different on that day. Thus, the constructions required the work not only of stonemasons (and architects) but also of sky peers. In truth, we do not really know what these large constructions were for: in Malta there are even two complexes, dating back to 5-6 thousand years ago, located at a distance of 500 meters), fig. 6.17a.

There are documents preserved (the clay tablet Mul.Apin with cuneiform writings, fig. 6.18a) testifying that eclipses were observed in Mesopotamia 3500 years ago; indeed, the geometric coincidences of the orbits of the Moon (and apparently) of the Sun with periodicity of 18 years are even now called by the Chaldean name "Saros". The Egyptians, almost three thousand years ago, knew how to calculate the volume of a truncated pyramid, how to approximate the irrational number π , and add the fractions with odd denominators, as evidenced by the papyri of that time (fig. 6.17c). The internal structure³⁸ of the great Egyptian pyramids, built almost five thousand years ago, still remains a mystery.

To build the colossi that in height (145 meters for the pyramid of Khufu, in Greek Cheops) almost exceed medieval cathedrals, considerable notions of mathematics were needed (2.3 million blocks of stone were used), geology (most of the blocks are made of sandstone, easy to cut, while granite was used for the walls of the pharaon's chamber, very hard), mechanics (water was poured under the sleds that transported the blocks, to compact the sandy soil, the largest block of granite brought to a height of 70 meters weighs 80 tons) and first of all an exceptional organization.

From the time of Pythagoras, music becomes a mathematical harmony: the flute no longer has five holes (as on the image in the Etruscan tombs) but seven, as in modern harmony (but only "Western", Korean music still has five tones). The frequencies of "harmonic" tones in the Pythagorean musical scale form the ratios of whole numbers, 1:2, 2:3, 4:5. But the Pythagorean theorem on the right triangle was known (and proven) a thousand years before him, as evidenced by the Babylonian tablet YBC 7289 of about 4 thousand years ago, see fig.

³⁸ K. MORISHIMA *et al.*, *Discovery of a big void in Khufu's Pyramid my observation of cos-mic muon*, «Nature», 552, (2017), p. 386.

6.17b. Thus, the Babylonians also knew the irrational numbers (the root of 2), only they used the system of calculation in fractions of 60.

The study of these ancient artifacts makes archaeology cross over into mathematics, or rather towards cognitivism, that is, towards the search for common modes of human thought. Not only did practical necessity push Man 5,000 years ago towards scientific discoveries, but also the joy of transmitting to others (i.e. even to us) the beauty and rationality of the external world.

The Copernican system, Kepler's laws, Einstein's equation of general relations are striking for their simplicity and elegance. Then, in practice, simple models develop through a series of corrections: the orbits of the planets are not perfectly coplanar, the orbit of Mercury is not exactly elliptical, the "subtle" effects of general relativity are several, such as the dragging of space-time ("frame-dragging"), etc.



Fig. 6.18. (a) The Babylonian tablet Mul.Apin of the seventh century BC is the earliest known compendium of astronomy; according to modern astronomers, the tablet records observations dating back to 1370 BC. (b) Tablet YBC 7289, dating from about 1700 BC., may be the first proof of the Pythagorean theorem; the cuneiform characters describe the development of the root of 2 (i.e., 1.4142 in decimal notation) in fractions with the denominator 60. (c) The Egyptian papyrus of Rhind, dating back to about 1550 BC., reports notions of geometry (the volume of a cylindrical granary) and algebra (development of fractions with the numerator series of fractions with odd denominators). SOURCE: Wikipedia.

At the same time that the developments in mathematics were documented, poetry was born. The famous Babylonian poem *Enuma Elish* (As above), composed in verse and recited on the feast of the Capodean, can be dated to the first half of the second millennium BC. The fragment on the birth of the world and the gods begins like this:

When the sky above had not yet had a name,
and below the mainland had not yet been named,

there was nothing but the primordial Apsu, their generator,
 and Mummu-Tiamat, she who begot all,
 and their waters were mechanized into a single body.
 Not yet had a hut of reeds been covered with mats,
 not yet had a marshy land emerged,
 Nor had any God been brought to be,
 their names had not yet been named,
 their destinies not yet determined.³⁹

Does the book of *Genesis* record such a "story"? Was it copied by the Babylonian or vice versa? Or are the biblical and Mesopotamian accounts similar, because the story of the creation of the world can not be different?

Modern genetics, linguistics and neuropsychology teach that the human brain has amazing abilities. But shall we call it brain or the human soul?

6.13. The immortal soul

The modern philosopher John Searle laments that "most people when asked about their identity claim to be essentially made up of body and soul, and some add even the spirit." Searle attributes "the blame for this confusion to Descartes and even before him to Aristotle, who was the first to speak of substance and essence"⁴⁰

Aristotle was, without a doubt, a "down-to-earth" philosopher. As a young man he swam, dived, tore fish, scanned the sky. He was the teacher of Alexander the Great; he wrote about poetics and ethics; his books on zoology for the richness of detail remain valid to this day; He is responsible for the invention of ethology, that is, the science of animal behavior.

In Book III of the treatise *De Anima* Aristotle describes the phenomena that today would be called the physiology of the senses and perception. Aristotle could not have known of the existence of two different receptors in the human eye, with sticks, separately sensitive to black and white vision (with low lighting) and color vision. How-

³⁹ *From the Nile to the Euphrates. Readings of Egypt, Assyria and Babylon*, edited by Alfonso Di Noia, Edipem, Novara 1974, p. 73.

⁴⁰ J. R. SEATLE, *Mind. A Brief Introduction*, Oxford University Press, New York 2004.

ever, he wrote, "the first thing we see is color." He could not have known that light is an electromagnetic wave emitted when the temperature of the body reaches a thousand degrees, but he wrote "light is not fire, nor a body, but something emitted by fire".

Nowadays it becomes difficult to identify the differences between humans and animals: even dogs feel emotions. It has recently been discovered that even plants use internal communication through electrical signals (see Fig. 6.20). The electrocardiogram (6.20a) is a periodic series of electrical signals, of a few mV and of different shapes, called P, Q, R. In the human brain, a stimulus, such as a triggering traffic light, causes an electrical impulse, of a few μV (micro, that is thousand times less than mV), which marks preparation, reaction and relaxation⁴¹. The signals are very fast, at the limit of physical possibilities.

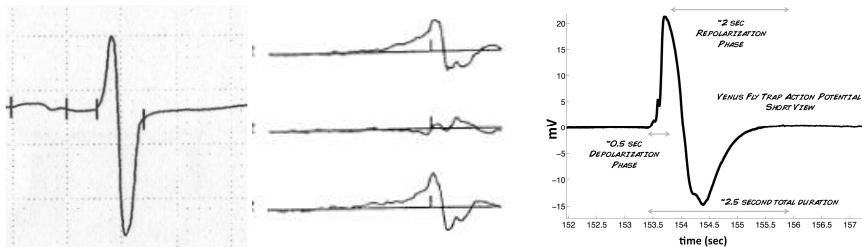


Fig. 6.19. Electrical signals in living organisms. (a) The electrocardiogram consists of a series of signals of a few mV lasting less than one second. (b) In the human brain, a stimulus causes a complex electrical impulse, lasting a few μV and lasting about 0.2 seconds. (c) In plants, the electrical signals emitted are mV but much slower: in the dionea, a carnivorous plant, the signal of the closure of the trap lasts 2 seconds. SOURCE: MK; G.A. CHIARENZA, Backyard Brains.

But plants also produce electrical signals, even if they are slow. The dionea (*Dionaea muscipula*), also known as the Venus flytrap, a carnivorous plant that captures insects, closes the trapping leaf if two sensor "whiskers" are touched at a distance of no more than 20 seconds: the electrical signal generated lasts 2 seconds⁴². The conclusion

⁴¹ G.A. CHIARENZA *et al.*, *Brain activity associated with skilled finger movements: Multi-channel magnetic recordings*, «Brain Topography», 3 (1991), p. 433.

⁴² Backyard Brains, Neuroscience for Everyone, https://backyardbrains.com/experiments/Plants_VenusFlytrap (accesso 8/5/2017).

of the graphs in Fig. 6.20 could be that there is no difference between animals, man and plants: and it is really a wrong conclusion!

From the observation of metabolism and electrical signals, it would seem that there are no substantial differences between plants, animals and humans. Or perhaps there is, at the biological level, only a different degree of complexity? Aristotle solved the question in a brilliant way, defining the three *types* of soul: the vegetable, which ensures mere existence (nutrition, growth), the animal, which also provides sensations and locomotion, and the human, which uses intelligence and imagination⁴³. Each type of soul incorporates the previous one, but the three types are completely different.

It would be difficult to attribute to Aristotle, who belonged to the Greek and pre-Christian rational world, the label of "idealist". But the Philosopher wrote about the human soul that "it has something divine." His commenter, Giancarlo Movia, writes: "If you read the text without prejudice, and keep in mind the cc. 4 and 5 of the third book, it cannot be denied that it substantially agrees with the doctrine professed by Aristotle in his published works, of the immortality of the human soul".⁴⁴

Affirmations about the incorruptible human soul appear in various places in the *De Animal*:

It seems, then, that the intellect comes as a substance and that it is not corrupted. [...] Thought, therefore, and intellectual activity, fails when an internal organ [i.e., the brain] is corrupted, but in itself it is impassable. To think, to love, or to hate are not the property of the intellect, but of that particular subject who possesses it, inasmuch as he possesses it. Therefore, when this subject is corrupted, the intellect neither remembers nor loves, since these functions were not its own, but of the compound that has perished. The intellect, on the other hand, is perhaps something more divine and impassive. (498b 18-30).

And there is an intellect analogous to matter because it becomes all things, and another that corresponds to the efficient cause because it produces so many. [...] And this intellect is separable, impassible, and unmixed, being act by essence, since what it does is always superior to what it undergoes, and the principle is superior to matter. [...] When it is separated, it is only that which is true, and this alone is immortal and eternal, but we do not remem-

⁴³ Vedi anche: G. KARWASZ, *Aristotle's three souls in modern science: Re-reading "De Anima"*, «Cauriensia» 13 (2018), pp. 429-448.

⁴⁴ G. MOVIA, in Aristotele, *De Anima*, Bompiani, Milan, 2014, p. 263.

ber, because this intellect is impassive, while the passive intellect is corruptible, and without this there is nothing you think. (430a, 15-30).

So, following Pope Benedict XVI, the immortality of the soul could be precisely the decisive characteristic of man.

Does the topic of the immortal soul fit into the book on science? Surely not! But even in physics we have several unproven and/or unprovable hypotheses. One of the explanations for the mass and charge of the electron (remember, the most elementary particle of all) assumes that the electron is a vortex of electromagnetic field, closed in on itself. The brain also produces electromagnetic waves (which are picked up with the electro-encephalogram). Is a set of very complex electromagnetic vortices self-sustaining? One would enter into the speculations of the New Age. We have so many arguments for the immortality of the human soul (first of all "the communion of saints", who was graced to touch it personally...) that we do not need hypotheses that go beyond scientific methodology: Galileo's physics applies to the material world and does not extend to the immaterial world ("heavens", according to the words of the book of *Genesis*).

Finally, we can quote Plato, who in the *Phaedo* discussed the question of the immortality of the soul and drew these ethical conclusions:

But even to this, friends, it is right that you should turn your minds, for if the soul is immortal, it needs care, not only for this stretch of time which we call life, but for eternity, and the danger may now appear very serious, if someone does not take care of it. For if death were a detachment from everything, it would be fortunate for the wicked who have died to detach themselves from the body and from their own wickedness together with their soul. Now, however, since it has become clear that it is immortal, there could be no escape from evils or salvation for it, except that it should become the best and most sensible possible. For the soul has nothing with it when it comes to Hades, but its own education and conduct of life, which things it is said to be of great benefit or harm to those who died at the beginning of their journey down there⁴⁵.

⁴⁵ PLATO, *Tutte le opere*. Vol. I, *Phaedo*, trans. G. Giardini, Newton, Rome 1997, p. 241.

6.14. Neither angel, nor beast⁴⁶

The question whether man is a being made only of physical matter, organized in a certain way, or made of two "substances", to use Aristotle's vocabulary, has an essential cultural, philosophical, political importance: the question of materialism defines the whole of human civilization. The denial of spiritual "substance" led in the twentieth century to the greatest disasters at the level of the whole of humanity: hundreds of millions of deaths under totalitarian regimes.

Modern neuroscience tries to *locate* our mental functions somewhere in the brain. So far, only very simplified conclusions have been reached: for example, if the frontal lobe is damaged, the patient loses his vision. This does not mean that a frontal lobe is enough to see. As Stanley Yaki, a Dominican and physicist, pointed out in his book *The Brain and Thought: The Strangest Union*⁴⁷, thought resides in the brain at the same time everywhere and nowhere. As Aristotle wrote, the soul is the *form and purpose* of the body.

But why do we need the brain, a tangle of protein filaments, to "house" the spirit? In theory, thought could also run on a circuit made of silicon, such as a computer. In any case, there is a need for a material substance, not only for "pure" thought, but mainly for communication with the external, physical world. Thus, in *De Anima* Aristotle describes the functioning of sight, hearing, touch.

The already mentioned John Searle complains that "ordinary people in Western culture believe that they possess body, soul and still something called the spirit" and that instead "most experts profess to be materialistic". Why is the opinion of the "people" (i.e. the vast majority of society) different from that of the "experts"? Usually the blame for this gap is attributed to Descartes, in particular to one of his last works, the *Meditations on primary philosophy*, that is, on theology. In this work, Descartes asked himself where in the brain lies the *common sense* that coordinates all the senses. Today we know that it is everywhere. Descartes also wondered if the human soul was immortal. His answer was: "The good Lord does not deceive us by promising

⁴⁶ P. PREMOLI DE MARCHI, *Man, neither angel nor beast. Arguments in favor of the existence and immortality of the soul*, I Quaderni del Timone, Edizioni Art, Novara 2005.

⁴⁷ S. YAKI, *The Brain Mind Unity: The Strangest Difference*, RVB, Pinckney 2004.

eternal life." A similar conclusion was drawn by his contemporary, Blaise Pascal. We will discuss this in Chapter VII.

The relationship between body and soul has been the subject of more complex reasoning in the history of philosophy. For Plato, the soul was independent of the body and in a certain sense infused into it. Aristotle, as already mentioned, had used the metaphysical concept of form: "the soul is the form and the end of the body". But with the destruction of a sculpture the material is disintegrated, but also the form disappears? In answering, St. Thomas emphasizes that the soul is *created* by God, so it exists as a *substance*. Man is the unity of soul and body.

Paola Premoli de Marchi explains it this way⁴⁸:

Thanks to this particular structure, of substance consisting of essence and act of being, the soul can inform the body, but it can also subsist separately from the body, has in itself a full individuality and incommunicability, and is simple and incorruptible. On the other hand, however, Thomas emphasizes that the relationship between soul and body is not accidental: on the contrary, it is part of the essence of the soul to be the form of the body, to constitute a substantial whole of the body. Therefore man is fully such in the compound of soul and body, and not as a soul separated from the body.

A frequent question is: what happens to the soul when the brain deteriorates, with age, for example? Aristotle also answered this question: the soul temporarily "withdraws", in a way similar to when one gets drunk: the soul has not vanished, but it does not find a substrate, a background, to "lean on".

Does the human soul then exist after death? All the cultures of *Homo sapiens*, from the Siberian cultures of the funerary rites of 40 thousand years ago and from that of the pyramids of ancient Egypt to Plato, have believed yes. And let us remember the *Phaedo* once again: what the soul carries with it when it passes to the other world is not only self-consciousness, but all the experiences, actions, thoughts, words and omissions of earthly life. And *Apostles' Creed* emphasizes that souls not only exist after death, but participate in our earthly life: the concept is encapsulated in the laconic "I believe in the communion of saints."

⁴⁸ P. PREMOLI DE MARCHI, *op. cit.*, pp. 54-55.

Thus man, even with all his defects and the sufferings that his life brings to the material world, differs even from the angels, who probably enjoy the material world little⁴⁹.

6.15. The world full of angels

The *Creed* does not refer to the existence of angels, but they are part of "all things invisible". Of the seven categories of angelic choirs (according to Pope Gregory IV) only the one on the lowest rung, precisely the angels, participates in our life. Of the second category, that of the archangels, only a few (Michael, Gabriel) occasionally descend into the material world to bring important messages. The Archangel Michael is also invoked in the prayer of Pope Leo XIII: "St. Michael the Archangel defend us in the battle against the evils and snares of the evil one; be our shelter [...]»⁵⁰.

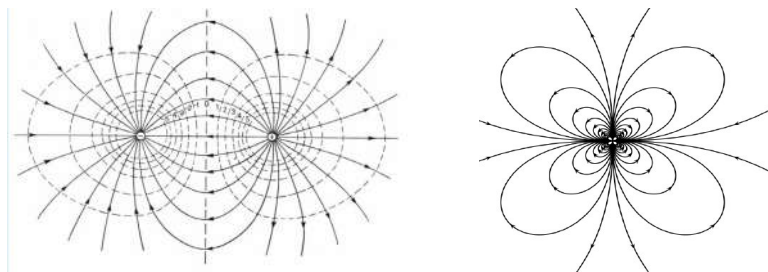


Fig. 6.20. The visualization of the electric field (invisible in nature) around the model charges: (a) two opposite charges (one dipole), (b) outside four charges of the same sign. Today, these distributions are calculated by computers; in the sixties, when Feynmann wrote his *Lectures*, a certain distribution had to *be assumed*, and then verified point by point. SOURCE: K. FEDUS, with thanks.

Richard Feynmann (1918-1988), one of the greatest theoretical physicists of the twentieth century (and a brilliant teacher), describing

⁴⁹ Paola Premoli de Marchi cites a different opinion, that of St. Thomas about angels: "Furthermore, the affirmation that the complete soul does not have in itself the complete species of man, but possesses it only if united to the body, explains according to Thomas its difference, in terms of perfection, with respect to the angels. These, in fact, are more perfect because they are contained, as species, in themselves, being spiritual substances" (*op.cit.*, p. 55).

⁵⁰ GIOVANNI PAOLO II, *Regina Coeli*, 24/04/1994, http://w2.vatican.va/content/john-paul-ii/it/angelus/1994/documents/hf_jp-ii_reg_19940424.html

the concept of the electric field, wrote⁵¹: "It is much easier to imagine an angel than the electric field. It is enough to draw a winged figure and then erase it, since angels are invisible. On the other hand, to find the configuration of an electric field, which is also invisible, one must first find the distribution of electric charges and then solve a suitable equation." In figure 6.21 you can see the configurations of the electric field calculated around the distributions of the model charges.

Pope Gregory the Great (540-601), a saint of the Catholic Church, had established that there were nine types of angelic choirs, counting from below: angels, archangels, up to cherubim and seraphim. Edward Lucie-Smith in *The Glory of Angels* writes: "According to the most widely accepted opinion, angels are divided into three categories. The first consists of cherubins, seraphim, and thrones. These angels, being the closest to God's throne, are incomprehensible to the human mind. [...] The third sphere consists of the angels to whom we are most assimilated, since they have direct contact with men."⁵²



Fig. 6.21. Today we are used to imagining angels as figures with white wings. In the Middle Ages, angels' wings shone with the colors of the rainbow. It is difficult to find representations of cherubim and seraphims⁵³, which "should" have three pairs of wings. Here is a fragment of *The Coronation of the Virgin with Adoring Saints* (1407-9) by Loranzo Monaco (National Gallery, London) and *The Annunciation* by Fra Beato Angelico (Convent of San Marco, Florence). PHOTO: GK 2004.

⁵¹ The concept of electric field is a bit bizarre: it is the space in which electric forces act on electric charges. The space we are talking about, in theory it is empty, it does not contain material particles, but it is not empty, since it is pervaded by the "electric field".

⁵² E. LUCIE-SMITH, *The Glory of Angels*, Harper Design, 2009.

⁵³ See for example, Pietro Cavallini (1240-1320), *Last Judgment*, Church of S. Cecilia in Trastevere, Rome, http://www.frammentiarte.it/dal_Gotico.it/Cavallini_opere/05-04_cavallini_giudizio_universale.jpg (accessed 05/05/2016).

6.16. By a Breath

This book, and in particular Chapter VI, may seem heterogeneous: on the one hand, it contains very scientific statements about the genome, DNA, proteins, neuro-signals; on the other hand, divagations that are not at all verifiable about the immortal soul and angels. But right in the middle between these two opposites is man, created in the likeness of God, molded of clay, but who has received the breath of God: the union between the material and spiritual worlds. "Then the Lord God formed man out of the dust of the earth, and breathed into his nostrils a breath of life, and man became a living person" (*Gen 2:7*).

In the Polish version, the "dust of the earth" is translated as "the clay". Having to choose between sand (SiO_2) and clay, the latter contains all the elements we are made of: calcium, oxygen, sodium, potassium, iron, hydrogen, except carbon. But to become "living" it is necessary that special organization of the chemical elements, which makes one plant grow and flourish, while another, in spite of all efforts, withers and becomes *inanimate matter*. Aristotle already distinguished the vegetable soul from the animal one. But in the case of man, "a breath of God" was still needed to create a *human person*.

The whole path of the evolution of the various pre-human forms once again emphasizes a clear detachment of man from the world of animals. *Homo erectus*, a great walker, was already different from chimpanzees in the way they occupied the environment, got food, used tools and fire.



Fig. 6.22. This image illustrates the words "[God] breathed into his nostrils a breath of life, and man became a living person." The word *person* means more than "a being". Aristotle emphasized the presence in man of the intellect, which has something divine. But the biologic difference between pre-human forms and Man is really "a breath". Source: La Cappella Palatina, Palermo.

But in a million years its evolution has remained at a standstill at that point. *Homo sapiens* in a tenth of this time has mastered the complex vocal communication, filled all the caves of the European Atlantic coast with some amazing drawings, built cities, not to mention the invention of opera and computers. Not a breath, but an abyss separates us from both chimpanzees and all pre-human forms. To be a Man, created directly by God, is a source of pride!

6.17. By the hand of God

In modern thermodynamics and even in theology, the concept of the self-organization of matter introduced by Ilya Prigogine (Nobel Prize 1977) is now widespread: snowflakes form beautiful stars. Yes, it cannot be excluded that in phase transitions the stability curves reach the maximum order and not the minimum. But from the laws of thermodynamics to a functioning biological cell the road is infinitely long; it is long even for single amino acids in the absolutely logical chain of billions of bits of DNA. We therefore do not agree with the concept of *self-emergence*, that is, of self-creation.

Nor do we agree with the idea of the *Intelligent Project*, according to which laws were incorporated into nature to allow the autonomous appearance of life and of man with his immortal soul. Recall that cosmologists, to explain something as simple as a (mysterious) distribution of galaxies, coined the expression "the finger of God". All the more reason for *Scripture*, which does not attribute all the beauty of the world to *self-emergence* or the *Intelligent Project*, but to God himself.

And God does not give the world just a single boost when it slows down, as *deists* would say: He monitors our life paths constantly. The Catechism of the Catholic Church says (art. 302):

Creation has its own goodness and perfection, but it has not come out of the hands of the Creator entirely completed. She is created "in a state of way" ("in statu viae") towards the ultimate perfection to which God has destined her, but which has yet to be attained. We call divine Providence the dispositions by which God leads creation towards this perfection.

6.18. They say, that He is risen⁵⁴

If several authors have sided with the immortality of the human soul in the history of philosophy, the only Christian religion insists on the resurrection of the body. "Yes, Lord, I know, at the end of time we will all rise again," said Martha, Lazarus' sister, who did not yet believe it. The empty tomb, as Messori emphasizes, is the most absolute basis of our Faith. But the account of the Gospel of John (*Jn 20: 5-7*) written by the one who was an eyewitness, is surprising for its laconic:

And, bending down, he saw the bandages on the ground, but he did not enter.

Then Simon Peter also arrived, who followed him; he went into the tomb and saw the bandages on the ground, and the shroud, which was on Jesus' head, not on the ground like the bandages, but folded up in a separate corner.

It sounds like a nurse's account to the head nurse: no Glory, no Hallelujah! The laconic nature of the description reproduces the amazement at what Peter and John saw inside the tomb: the shroud flogged, the linen not unrolled, on the ground, as if the body had escaped. Jokingly, I often say that in my anti-matter laboratory we do similar experiments: an anti-electron when it collides with an electron simply evaporates, that is, it converts into two gamma photons that pass through the container; the matter has disappeared. But it's just a joke. Non-believers have never explained why the Shroud was found laid on the pavement. And perhaps this almost absurd laconic is proof of the authenticity of the Gospel account.



Fig. 6.23. The Church of the Holy Cross in Jerusalem in Rome: the "INRI" tablet, and the Cathedral of Oviedo: the shroud that covered Christ's head. PHOTO: GK 2011, 2018.

⁵⁴ V. MESSORI, *They say that he is risen. An investigation into the empty tomb*, SEI, Turin 2000.

Pierluigi Baima Bollone has identified on the Shroud the imprints of two Roman coins, one from 27 AD and the other from 29 AD, placed on the eyes (as the Greeks did with the dead). Even the texture of the fabric is peculiar: of a type made only in Egypt two thousand years ago. The only evidence against the authenticity of the Shroud was produced by physics, through the examination of radioactive carbon ^{14}C . This isotope is formed in the atmosphere, is absorbed by plants, and after decay (with a characteristic time of 5600 years). The dating made in three laboratories suggested that the Shroud dates back to the Middle Ages. But as an experimental physicist I have serious doubts about this conclusion.

It is inexplicable, in the first place, how the Image was formed. It is not a dye, it is not a print; it seems that the fibers of the linen themselves have undergone a change. Because of what? Of a very powerful nuclear radiation, as in the transformation of matter into *gamma rays*? But where did the positively charged electrons come from? An absurdity! In addition, the Shroud suffered a fire in the chapel where it is kept in Turin and other very complicated historical events.

It is difficult to apply the radioactive carbon test to the dating of something that already escapes physical explanation, unless one wants to show that in the case of linen fabrics modified with unknown radiation the scientific tests simply fail. This would be a correct deduction, after years spent personally (GK) in experimental fatigues.



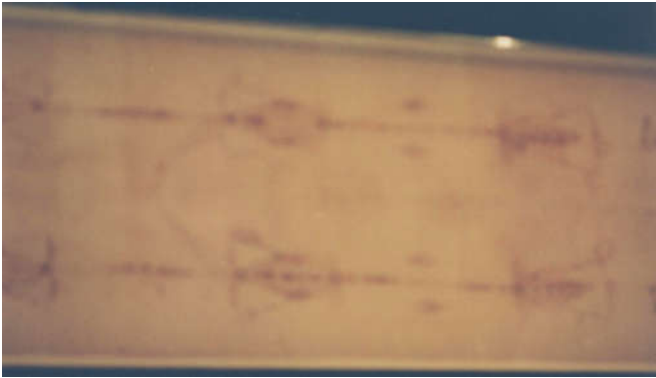
Photos. 6.24. (a) Some olive trees live hundreds of years. This grows in the Garden of Gethsemane, at the gates of Jerusalem. (b) The silver star in the Basilica of the Nativity in Bethlehem. PHOTO: MARIA KARWASZ, 1999.

But the image on the Shroud seems to fade slowly. The more scientific evidence we have, the less can be seen with the naked eye: we *have* to believe. Vittorio Messori writes "*chiaroscuro*" (light and shad-

ow): scientifically *proven* religion would not need an *individual* faith⁵⁵. Images, scientific facts, personal testimonies can strengthen the Faith, never replace it.

6.19. The Two Worlds

Man, with his body made of biological matter and his *psyche* elusive to physics, is a bridge between two worlds. But the bridges can vary: one rests more on the sky, the other is firmly linked to the earth. The saints, the friars, the nuns, the priests, the prayer, the miracle rest more on the other side⁵⁶. Our prayers, charity, fasting, and all works of mercy are also *shortcuts* to the heavenly world. But this would be a topic for another book...



Photos. 6.25. Another photo, testimony of the pilgrimages of the author and his wife (Turin, 2010). The imprint of the face of the dead (and risen) Christ: the central image of the Christian Faith, is barely visible in the center of the painting. Intense stains are due to the burns. PHOTO: GK, 2000.

⁵⁵ The books that have influenced my conviction of the authenticity of the Gospel accounts of the Passion are: *The Day Christ Died* by Jim Bishop (1958); *He suffered under Pontius Pilate* and *They say that he is resurrected* by Vittorio Messori; 2015. *The New Investigation on the Shroud. Two thousand years of history and the latest scientific evidence* by Pierluigi Baima Bollone, professor of forensic medicine in Turin and even more so his previous book *Shroud. Storia e Scienza*, Priuli e Verluca, 2010; S. Gaeta, *L'altra Sindone. The True Story of the Face of Jesus*, Mondadori, Milan, 2005. Mel Gibson's film *Passion* also remains poignant in its realistic documentation.

⁵⁶ We recommend another book by Vittorio Messori, *The Miracle*, with a very well-documented description of the miracle that occurred to Miguel Juan Pellicer in the year 1640 in Zaragoza: the "de-amputation" of a leg, which the Italian version of Wikipedia defines as "an alleged miracle".

Testimonials

7.1. Humanities and "exact" sciences

Often, indeed almost always, the two branches of knowledge – natural sciences and humanities – are opposed. It is difficult to find more erroneous attitude than this, for many reasons.

1) The natural, mathematical and physical sciences operate on nature, that is, on real objects that exist independently of human presence. The human sciences operate on human artifacts: written thoughts (philosophy), individual behaviors (psychology), group behaviors (sociology), sequences of human events (history), aesthetic artifacts (art, music).

On tastes, it has been said, one should not discuss. And in the "exact" sciences it seems that every evaluation is absolute, that is, objective, and not subjective. It is even said that "mathematics is not an opinion". Then, in practice, the science of statistics are used to *interpret* both physical¹ and social phenomena.

2) Thus, in the human sciences every judgment can be *interpretive*. But in the physical sciences it is the same! For Newton, light was particles, *corpuscula*. He was the first to describe mathematically the construction of lenses (which one focuses, and another enlarges), using Snelius' law of refraction: the angle of refraction (in glass) is less than the angle of incidence. This law can be interpreted in a very didactic, but little scientific way, assuming that glass, heavier than air, "attracts" light particles. This is an *interpretation*.

¹ Attributing "absolute" certainty to experimental data is subject to a *convention*: these conventions are different in elementary particle physics ("5 sigma"), different in repeatable multi-type measurements (the Gaussian distribution), different on elementary particles, different in genetics, different in cosmology (the Big Bang is not a repeatable experiment), vedi G. GIGERENZER, *Quando i numeri ingannano*, Raffaello Cortina, 2003.

Physicists have found a consensus on the wave-corpuscular dualism: in some experiments light demonstrates its photonic nature, in others behaves like an electromagnetic wave. But at this point a question arises: can we interpret other phenomena in dual and/or multiple ways? Yes! Many of them.

The whole history of physics (and beyond) is a chain of different intertwined interpretations. For Copernicus, Ptolemy's data (and his observations) were an argument for heliocentric theory. For Tycho Brahe, with its very exact measurements, they were an argument for a mixed system (see figure below).

Is Schrödinger's cat alive or dead? It depends on the interpretation, or rather on the type of experiment that will be carried out: an object, an electron for example, exists "in itself", described by its wave function Ψ . If the experiment measures the x-position, the velocity will be roughly indeterminate. Mathematically, the *convolution* $\Psi * X \Psi$ of the operator X of the position measurement is made with the wave function. In a "visual" way we can say that we have made the "projection" of the wave function on the position operator (see fig. 7.1).

I would not like to be accused of scientific relativism: no! I only note that in the "exact" sciences every datum always requires interpretation, exactly like it is also as in human sciences.

3) Are the exact sciences based on objective data and the humanities on judgments? Above we discussed that data require interpretation, but there is more: the exact sciences always seek support in the judgments of other scientists, that is, in opinions. In other words, the natural sciences also ask for humanistic data.



Fig. 7.1. Two images to underline that even the "exact" sciences are subject to human interpretation. (a) Tycho Brahe's system, a mixture of Ptolemaic and Copernican: wrong, but it reproduced well the apparent motions of the planets. (b) The "Schrödinger" cat - a bit in profile, a bit *en face*: in quantum physics the measurement consists of a "projection" of the proper state of the system, unknown, with a defined mathematical operator chosen for the measurement. PHOTO: GK.

Copernicus himself is an example: before bringing mathematical arguments (observations and calculations) he calls into question Pythagoras as a supporter of the theory of the motion of the Earth. In fact, he wrote²:

Moreover, as the sky contains and constitutes a commonplace for all things, why should it not be static and motion should be attributed rather to the things contained and not to the container? Of this sound conclusion that the terrestrial world revolves were Heraclitus and Ephaantus Pythagorians and Nicetus of Syracuse, according to Cicero.

And to justify the relativity of motions, Copernicus cites the Aeneid: "it seems that the earth vanishes, instead this is the ship that moves away".

4) The relative balance: data obtained from nature ↔ arguments reported by other authors, with the passage of time it moves towards humanities – it is necessary to cite more and more authors (and their experimental data, trusting their procedures). Then, with the passing of the centuries, even the exact sciences become humanistic³.

5) The last argument for the methodological unity of the two sciences is the author: man. If we believe in the intellectual and emotional unity (equality?) of all men, the results of their mental activity must also be compatible with each other.

In summary, all opinions on different topics are equivalent and all must be taken seriously.

7.2. Plato: The Immortal Soul

We have already mentioned Plato's opinion, almost certainty, on the immortality of the human soul and the consequences that this immortality creates for ethics. Let us quote a few more fragments on the soul of *Phaedo* (XXIX):

² «Cumque coelum sit quod continet et caelat omnia communis universorum locus, non statim apparet, cur non magis contento quam continenti, locato quam locanti motus attribatur. Erant sane huius sententiae Heraclides et Ecphantus Pythagorici, ac Nicetas Syracusanus apud Ciceronem, in medio mundi terram volventes.» Nicolaus Copernicus, *De Revolutionibus orbium coelestis*, Petronius Editions, Norimberga, 1543 Liber I, Caput 5.

³ But this was also the case in Aristotle's time: from his writings we know the four "elements" of Empedocles.

Therefore, if this is his condition, he will not go to that place that suits him, to the invisible, to the divine, the immortal, the intelligible, where, once he arrives, he will be happy, free from error, from wickedness, from fear, from wild passions, from all the other evils of man, and where he will be able to spend all the time that has happened, as they say with regard to the initiated, truly, in the company of the gods. Is that or not, Cebes?"

This tranquility, almost certainty about one's own destiny is absent in Marcus Aurelius who, while building a valid (from the human point of view) ethics, felt the passing character of all events, their disappearance, merging, disintegrating without traces. Marcus Aurelius wrote in the *Memoirs*⁴:

In perpetual succession there is an anxiety to come into being, an anxiety to support itself; and in the thing that has come to light, at once some part is extinguished. A perennial flow, a perennial transformation ceaselessly renew the world; just as the incessant vicissitudes of time continually make infinite duration new. (*In this flood*, Book VI, 15)

Universal nature with universal substance as wax fashioned a horse; then it remelted it to form a tree, using the same material that contrived it; then a man, then anything⁵ else. And each of these individuals had subsistence for a very short time. On the other hand, it is certainly not a bad thing for a coffin to be *undone*, nor to have been devised (*For a very short time*, L. VII, 23).

The dead do not give way out of the world. If it remains here, it also undergoes transformation and dissolves into its own elements, which are the *elements of the cosmos*⁶ and yours. And these elements are then transformed in turn and do not complain about it. (*Transformation*, Book 8:18).

Clearly, Marcus Aurelius did not *believe* in the immortality of the human being, nor of the soul nor in the resurrection of bodies, so his ethics muddled through insecurity. The conviction of the superior Being, who protects and sustains us, removes pessimism both in the present and in the future.

Returning to Plato, his concept of soul and body was not that of the "bonnet" but of an integrity between body and soul. A Polish doctor (and friar) Jacek Norkowski⁷ points out that according to Plato the soul resides in the whole body, and not only in the brain. On the contrary, placing the soul in the brain opens dangerous avenues of "engi-

⁴ MARCO AURELIO ANTONINO, *Ricordi*, trans. Enrico Trolia, Fabri Editori, Milan 1995.

⁵ GK emphasized: The speech seems to be a premise of nineteenth-century materialism.

⁶ Here we have the pre-elements of today's cosmic "religions," such as New Age.

⁷ J.M. NORKOWSKI, *Brain based criteria for death in the light of the Aristotelian-Scholastic anthropology*, «Scientia et Fides», 6/1 (2018), pp. 153-188.

neering" of the human body. Either the unity of body and soul (the duality of the human being as professed by Pope Ratzinger) or expressed in other terms by Aristotle: the soul that constitutes the *form* of man.

7.3. Aristotle: The four causes

For an experimental physicist, Aristotle's most significant legacy should be the division of sciences between physics and metaphysics. However, paradoxically, his *Physics* is criticized by physicists themselves. In fact, it is a somewhat surprising book. Today, we divide physics into mechanics, thermodynamics, optics, electromagnetism. In Aristotle's time the four states of matter (solids, liquids, gases and plasma) were just defined (by Empedocles). But *Physics* does not deal with any of these topics – but constitutes to all intents and purposes a book of philosophy, in its profound principles. Aristotle deals with the definitions of space, time, and motion in their general sense.

Space for Aristotle was the distance between a material body and another. Thus, empty space makes no sense. As we discuss below, Galileo (and Descartes) introduced the concept of mathematical space that is completely empty. But for Albert Einstein (even more so for George Lemaitre), without the matter (i.e. bodies) space makes no sense: after two thousand years, physics returns to Aristotle.

Time for Aristotle is a continuous set of moments of "present". Despite several attempts, physicists have not been able to find the "quanta" of time – it always remains continuous. Aristotle wrote that time is the same everywhere: even if Einstein's relativity defines local reference frames, they can be coordinated at the "zero" moment. But the "before" and "after" time, as Aristotle notes, are *not* the same.

On motion, Aristotle wrote: "Then the body either remains at rest or moves in infinity, until it meets some heavier body" (*Physics*, IV, 215a). In modern language, this statement corresponds to Newton's first law, and in addition to the principle of conservation of motion. Having said this, it is advisable to read Book II with the greatest attention⁸, on the causes of motions, and on changes in general.

The four causes (matter, form, executor and purpose) defined by Aristotle, are usually associated with *Metaphysics*; however, all caus-

⁸ ARISTOTELE, *La Fisica*, ed. Luigi Ruggiu, Rusconi, Milan 1995, pp. 59-105. ARISTOTLE, *Physics*, trans. R. P. Hardie & R. K. Gaye, <https://classics.mit.edu/Aristotle/physics.2.ii.html>

es, including the fourth, teleological, already appear in *Physics*. He speaks about the *cause* as a goal, a purpose, an end. "Again (4) in the sense of end or 'that for the sake of which' a thing is done, e.g. health is the cause of walking about." (194b, 35). But if in human actions it is easy to determine the final cause, its existence is not obvious in nature. But Aristotle insists that the final cause also acts in nature: "Therefore action for an end is present in things which come to be and are by nature." (199a, 10)

And then Aristotle continues (*Physics* 199b, 16-18) and (200a, 33):

But the person who asserts this entirely does away with 'nature' and what exists 'by nature'. For those things are natural which, by a continuous movement originated from an internal principle, arrive at some completion: the same completion is not reached from every principle; nor any chance completion, but always the tendency in each is towards the same end, if there is no impediment. [...]

Both causes must be stated by the physicist, but especially the end; for that is the cause of the matter, not vice versa; and the end is 'that for the sake of which', and the beginning starts from the definition or essence;

In *Physics*, Aristotle also indicates the need for the existence of a *first* cause of motion. "The following argument also makes it evident that the first movent must be something that is one and eternal." (259a) We quote Aristotle so extensively, since he represented pure reasoning, even before the Christian faith. The same arguments – on the eternity of motion and the final cause in nature – will return to St. Thomas, but Aristotle's testimony is particularly valuable.

7.4. Thomas and the matter

St. Thomas (1225-1274), as the introduction to all the other questions of theology⁹, gave, in a rather laconic way, five proofs (or rather "ways") to demonstrate the existence of God: 1) of the first motion, 2) of the efficient cause (the first cause, that is, the root of the whole infinite tree of cause-effect dependencies), 3) of the necessary being, the only one that cannot be contingent (i.e. random), 4) of the perfect being – most rational, the best, etc., 5) of the rationality of nature.

The first way, of motion, goes back directly to Aristotle. In the restricted interpretation, according to the principles of today's physics, it

⁹ TOMMASO D'AQUINO, *Summa teologiae*, I^a q. 2 a. 3.

would be called "the first source of motion" and resembles the principle of conservation (of momentum, see par. 2.2). But the principles of conservations in physics regard not only the momentum, i.e. the motion. Also the matter and energy, in almost infinite quantities in our Universe, are subject, according to *beliefs* of physicists, to the principle of conservation: it was not the Big Bang *who* created the matter.

So, the first "way", as defined by St. Thomas, goes beyond physics, using Aristotle's terms – of power and act (*energeion* in Greek). St. Thomas is astonished by the ability of matter (and not only matter) to *become*. He mentions the *ability* of wood to burn, but all the "becomings" in nature are, if you think about it, miraculous: carbon, oxygen and nitrogen atoms to form proteins, proteins to form a sequential code called DNA, chemical molecules to form the biological cell, neurons to "create" consciousness, etc. – surprising that all this does exist, rather than does *not* exist. There must be the Prime Mover. In fact, the Latin name for the first way is *ex motu et mutatione rerum* – from the motion and *mutations* of things. Then, this "becoming", the continuous transition from "I can" to "I am", is not accidental, but as already noted by Aristotle, it continues towards a goal, the end and has its hidden order. The question is made more clear in the 5^o way.

The fifth "way" continually springs from our wonder of nature. As Eugenio Corti wrote¹⁰, just the sight of a colored butterfly that rests on the sand of a trench is enough to "show the existence of God". In the Middle Ages, the desire to seek order in things allowed the birth of modern science. As Stanley Yaki notes, no other culture – Egyptian, Greek, Chinese, Islamic – has succeeded in creating the free exchange of different opinions, which proliferates not only in the inner circle, but influences the way of thinking of entire societies. It was the Franciscan Roger Bacon (1214-1292) who posed the question of the precession of the day of the equinox and Jean Buridan (1300-1358), the rector of the University of Paris and canon in Arras, who defined the concept of *impetus* (i.e. inertia, i.e. formulating Newton's first law). From their work started the last medieval scientist and the first modern – Nicolaus Copernicus, canon in Frombork. As Newton said: "we have built our knowledge on the backs of giants".

¹⁰ E. CORTI, *Gli ultimi soldati del re*, (Last soldiers of the King) Ares, Milan, 1994, p. 204, quoted by G. Samek Lodovici in *L'esistenza di Dio*, I Quaderni del Timone, Edizioni Art, Novara, 2004, p. 12. We recommend also the book by Eugenio Corti "The red horse", on the battle of Stalingrad.

St. Thomas, in *Compendio di Teologia*, asks the question of matter and its diversity. For Empedocles, matter was composed of four elements (earth, water, air, fire), for Democritus they were variants of identical atoms. For J. J. Thompson, at the turn of the nineteenth and twentieth centuries, the answer seemed easy: a positively charged pudding with pieces of sultanas inside, i.e. the electrons with the negative charge. The model did not last long, already in 1911 it was abolished by the discovery of the nucleus, more or less point-like. Until Bohr's postulates, it was not clear how such a system could remain stable, see chapter III.

The whole of the twentieth century has accumulated growing doubts about the nature of matter: thanks to $E = mc^2$ one particle can be converted into another, regardless of their masses (but following the precise *principles* of conservation, electric charge, lepton charge, spin, etc.). Today, for the moment, the electron (and the two light quarks) seem elementary, but there are many other particles needed for the so-called *Standard Model* of particles. The question of whether there is a commodity, for example the primordial one of the inflation era, remains still open.

Aristotle accepted neither the atomism of Democritus nor the four elements, so to explain the diversity of *substances* he needed many different materials:

As regards material substance, it must not be ignored that, even if all things derive from the same original element or from the same original elements, and even the same matter serves as a starting point in their generation, nevertheless there is a matter which is proper to each thing. For example: the raw material of phlegm are the sweet elements, fats, while the matter close to bile is the bitter or other related elements. And these certainly derive from the same element.¹¹

To allow transformations, however, it was also necessary to accept the changes in matter, so wine is transformed into vinegar, that into water and water again into wine.

Of the same object, then, there are several materials, when one matter is in turn the matter of another: for example, phlegm is derived from fat and sweet, if fat is derived from sweet; but it can also be said that it derives from bile, as bile can be considered resolved in the raw material. In fact, one thing derives

¹¹ ARISTOTLE, *Metaphysics*, L VIII, 1044a, 15-20. [provisional translation]

from another in two ways: in so far as one derives immediately from the other, or in so far as it derives from the elements into which the other has been resolved.¹²

Aristotle's explanations are quite confusing. On the diversification of matter, St. Thomas Aquinas, in the "*Theological Compendium*", presents a revolutionary idea, both in comparison with Democritus and Aristotle. In fact, St. Thomas writes that the whole (material) world is made of the same one matter, *since God's creative action* did not require a previous matter. Thus, the differences between objects are caused by the different arrangement and/or organization of this matter in the hands of God (*Compendium of Theology*, Chapter 71: *The Diversity of Matter Is Not the Cause of the Diversity of Things*)

123. From what has been said above [i.e., that the creative faculty belongs only to God] it is clear that the diversity of things is not caused by the diversity of matter. For it has been said that matter is not presupposed to the divine action by which God produces things in being. Now the cause of the diversity of things does not derive from matter except in so far as matter is presupposed to the production of things, that is, when, according to the diversity of matter, different forms are introduced: therefore matter is not the cause of the diversity of things produced by God.

124. Again. In the same way that things have being, so they have unity and plurality, for everything in so far as it is being is also one. Now forms do not have being because of matter, but rather the opposite; for act is more excellent than power, and that by which a thing is necessarily more excellent. The forms, therefore, are not different because the materials are different, but rather the materials are constituted differently in order to be adapted to the different forms.¹³

Matter, being created from nothing, could not introduce the diversity of forms by itself; then it is the form that determines the diversity of objects and the multitude (but not the infinity) of objects reflects the (unique) perfection of God.

On the diversity of matter, modern chemistry gives a similar answer: electrons in themselves are indistinguishable. But an almost metaphysical principle called the "Pauli's exclusion," which does not allow two electrons to occupy the same quantum state, creates from an unformed matter all the variety of objects in this, wonderful world.

¹² *Ibid.*, 1044a, 20-24

¹³ THOMAS AQUINAS, *Compendium of Theology*, trans. P. Agostino Selva, Ed. Studio Domenicano, Bologna (1995) p. 95, provisional translation.

Let us also remember that the fifth way of St. Thomas is not only "the order of things" but the intrinsic teleology of the nature (and of man). Order alone, i.e. the laws of physics embodied in nature, could degenerate into a concept of "intelligent design": nature acts sensibly because it was *programmed* (in the distant past) by God. But to say that every action of nature, including the actions of man, serves a pre-determined purpose (which is, of course, clear only in the divine mind) has other consequences: is it not God who defines this purpose for each individual? Then the creation of the world continues, as the Catechism of the Catholic Church says (art. 302-303¹⁴):

302. Creation has its own goodness and perfection, but it has not come out of the hands of the Creator entirely accomplished. She is created "in a state of way" ("in statu viae") towards an ultimate perfection to which God has destined her, but which has yet to be attained. We call divine providence the arrangements by which God leads creation to this perfection.

303. The testimony of Scripture is unanimous: the solicitude of divine Providence is concrete and immediate; It takes care of everything, from the smallest things to the great events of the world and history. The Holy Books forcefully affirm God's absolute sovereignty over the course of events.

St. Thomas, teaching in Paris in the seventies of the XIIIth century, found himself in the midst of bitter disputes over certain theological theses, including the eternity of the world. To defend Creation, St. Thomas relied on faith¹⁵: today we can use scientific evidences from physics and cosmology to "prove" the Big Bang. But for diversity of the (chemical) matter, we still use a rather metaphysical concept today. Thus, the boundaries between faith and science are constantly moving, in different directions, with mutual benefits.

7.5. Copernicus: There will be fools

Nicolaus Copernicus was born in Toruń, a city founded by the Teutonic Knights. It was the year 1473, twenty years after the fall of Constantinople. He studied in Padua (1501-03), at the University of the Republic of Venice, in a multicultural environment. Before that in

¹⁴ http://www.vatican.va/archive/ccc_it/documents/2663cat017-308.PDF, p. 100

¹⁵ „Respondeo dicendum quod mundum non semper fuisse, sola fide tenetur, et demonstrative probari non potest, sicut et supra de mysterio Trinitatis dictum est.” S. Tommaso, *Summa teologiae*, [30420] I^a q. 46 a. 2 co <http://www.carimo.it/somma-teologica/somma.htm>

Krakow (1492-96), and then moved to Bologna (1496-1500), in full ferment after the discovery of America. In the Jubilee Year Copernicus stayed in Rome, and after a few months in Poland, in 1501 he returned to Italy. He obtained a doctorate in civil law in Ferrara (1503).

In Padua Copernicus officially studied medicine, but he bought all possible books and made astronomical observations with his Italian colleagues. In Poland he became neither bishop nor university professor, but was in charge of the administration of the Curia of Frombork in Prussia (and continued his observations). Already in 1515, somewhat at the urging of Pope Leo X who wanted the reform of the calendar, he had prepared the cardinal points of his theory: the Earth not only moves, but performs three motions - the rotation, the revolution around the Sun and its axis "swings", like a spinning top, with the period of about 28,000 years (this motion is called now "the precession of the axis of rotation").

In the meantime, Martin Luther split the Western Christian world in two: Prussia was divided into the Catholic zone, which was part of the Kingdom of Poland, and the Protestant part of the Principality of Hohenzolern. Frombork is located on the border of two zones. Paradoxically, *De Revolutionibus orbium coelestis*, is finished with the help of a young German mathematician, Johanes Retyk¹⁶, a professor at Wittenberg, and printed in Nuremberg, the "lair" of Protestantism, despite Luther's negative opinion¹⁷.

Copernicus, the canon of the cathedral in Frombork, understood well that his theory ousted the central role of the Earth and that for this reason it could be strongly criticized. In the letter of dedication to Pope Paul III, Copernicus wrote¹⁸:

I am well aware, O Most Holy Father, that as soon as some people become aware of the fact that I, in these books of mine which I have written on the revolutions of the spheres of the world, attribute certain movements to the earthly globe, they will immediately cry out that I and my opinion are to be

¹⁶ His family name was Lauchen, and he was born in Feldkirch, Austria. His father, a doctor, was accused of magic and beheaded. The son was forced to change his name.

¹⁷ "Nicolaus Copernicus tried to prove that this is the Earth not the sky, the Sun and the Moon [...] that moves and rotates. This fool has started to overthrow all astronomical knowledge. And instead the Scripture says that Josue ordered the Sun to stop, not the Earth" – free translation from Martin Luther's diaries. See also: <http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit3/response.html>. [*]

¹⁸ See for example on-line: SAVERIO CANTONE, http://www.saveriocantone.net/profcantone/fisica/galileo/copernico_DE_RIVOLUTIONIBUS_sottolineato.pdf [*]

banned. Nor, on the other hand, am I so rigidly attached to my own ideas that I do not take into account the judgment of others. Although I know that the philosopher's thoughts are far from common opinion, precisely because his first task is to seek truth in everything, at least within the limits granted by God to human reason, I nevertheless think that opinions that stray entirely from the right path are to be avoided.

Copernicus' model, with planets rotating on circles around the Sun, is much simpler (and more elegant) than Ptolemy's model with concentric and epicyclic circles rotating on them. In the foreword to *Revolucionibus*, Copernicus expresses his admiration for God's work:

For what is more beautiful than heaven, which contains all beautiful things? Which, moreover, the names Caelum and Mundus themselves indicate, the former referring to purity and ornamentation, the latter to chiselling. Most philosophers, precisely because of its exceptional beauty, have called it the visible God.

The explanation of his theory (L. I, chap. X) Copernicus ends like this¹⁹:

From Saturn, the highest planet, to the fixed sphere [of stars] the distance is enormous, as shown by the twinkling light [of the stars]. This indicates the essential difference between planets that move and stars that do not.
So perfect is the divine Opera Massima.

On the intrinsic limits of our knowledge according to Copernicus we have already written. Here we quote again a sentence from the introduction to *De Revolutionibus*: "Thus, with the help of God, without whom we can do nothing, I will try to make more detailed investigations into this with regard to the other stars."

On Copernicus' work it has been said: "the least read book in history". It is a book full of observations, numerical tables, diagrams. In fact, the first print run was 200 copies. Only with Galileo, and his *Dialogue on the two greatest systems of the Ptolemaic world, and Coper-*

¹⁹ «Quod enim a supremo errantium Saturno ad fixarum sphaeram adhuc plurimum inter-sit, scintillantia illorum lumina demonstrant. Quo indicio maxime discernuntur a planetis, quodque inter mota et non mota, maximam oportebat esse differentiam. Tanta nimirum est divina haec Opt[imi]. Max[imi]. fabrica.» https://la.wikisource.org/wiki/Pagina:Nicolai_Copernici_torinensis_De_revolutionibus_orbium_coelestium.djvu/33. Interpretazione: GK

*nican*²⁰ written in Italian, did Copernicus' work focus the attention of the whole of Europe.

7.6. Galileo: The scientific method

Talking about the first moments of the Universe, as in paragraph 4.9, is extremely risky: physics goes beyond the limits that it set itself at the beginning of the modern era. It was Galileo who formulated the fundamental canons of physics. Aristotle, perfect in his observations of the animal world, does not report accounts of any physical experiment. Ockham, Roger Bacon, St. Thomas always remained on the metaphysical level. It was not until 1543 that Copernicus' *De revolutionibus* was published, a true experimental treatise: a report of infinite observations, cataloguing, calculations and models. But it was still a book about the sky, not about terrestrial objects.

Galileo was the first scientist not to make abstract reasoning but to propose concrete, well-defined experiments, *repeatable* at any time in history (today, 400 years later) and in any place: throwing stones from the tower of Pisa by undisciplined tourists or on the Moon, by curious astronauts²¹.

We can bet that Galileo threw stones from the tower of Pisa which was already hanging²² in the construction phase. Galileo did not describe his experiments, well aware that it was not a recommended experiment (and today, with surveillance cameras it is strictly forbidden!). Rather, he proposed a *verifiable way* (although the description remains a bit confusing):

Before anything else, it must be considered that the movement of the heavy descendants is not uniform, but departing from rest they are continually accelerating; an effect known and observed by all, except by the modern author, who, not speaking of acceleration, makes it equal. But this general

²⁰ G. GALILEI, *Dialogo dei Massimi Sistemi*, edited by Ferdinando Flora, Oscar Mondadori, Milan 2004. We recommend reading the concise (and precise) introduction.

²¹ The Apollo 15 astronauts brought a feather and a hammer to the Moon: it was filmed and transmitted to Earth that the two objects, in the absence of air, fall at equal times.

²² The Tower was in danger of falling for a century (until 1997): constantly tilting since its construction in the twelfth century (for this reason the works were suspended in the fourteenth century), in the twentieth century its center of gravity was already out of the base. According to the laws of statics it should have already fallen. There has been a long debate on how to straighten it out: by pulling, supporting, digging? In the end, a project led by Prof. Andrzej Jamiolkowski from the Polytechnic University of Turin won and was successfully implemented.

knowledge is of no avail, unless it is known in what proportion this increase of velocity is effected, a conclusion which has hitherto been unknown to all philosophers, and first found and demonstrated by the Academician, our common friend, who, in some of his writings not yet published, but in confidence shown to me and to some other friends of his, shows how the acceleration of the right motion of bodies is made according to the unequal numbers *ab unitate*, that is, that once we have marked which and how many equal times are desired, if in the first time, the moving from the rest will have passed such a space, as for example, a reed, in the second time it will pass three can-ne, in the third five, in the fourth seven, and so consequently according to the following numbers, which in sum is the same as to say that the spaces passed by the movable, starting from the rest, have a proportion between them twice as much as that of the times in which these spaces are measured, or we mean that the past spaces are between them like the squares of the times.

Today we simply write

$$s = \frac{1}{2} at^2,$$

where s is the distance covered from the beginning of motion and t the time elapsed. Then, taking two successive moments t and $t + 1$ (and substituting 1 instead of $1/2 a$) we obtain the distance covered *between* these moments $\Delta s = [(t+1)^2 - t^2] = (2t+1)$ which remains an *odd* number ("caffo", as Galileo wrote).



Fig. 7.2. (a) The work, led by Professor Jamiołkowski, of "straightening" the Tower of Pisa; it was already pending in Galileo's time. (b) The idea of accelerated motion was taken up by the Korean architects who designed the tower at the Science Museum in Daejeon, Korea. (c) A child marvels that the heavy and light trolley descends with the same "speed". MARIA KARWASZ PHOTOS, GK LESSON.

With Galileo, for the first time, mathematical laws were applied to physics, different from Ptolemy's epicycles, that were some perfect

wheels rotating at a constant speed. Galileo did not yet use arithmetic symbology, but he paved the way for Newton's *The Mathematical Principles of Natural Philosophy* (1688). Let us quote E.M. Rogers again: "Physics descended from heaven to earth along Galileo's inclined plane".

In the context of Galileo, we can define a second "razor". The first, attributed to Ockham (although not expressed directly) states that one must not multiply concepts outside of those necessary. We can express "Galileo's razor" as follows:

Anything that has not been verified (with an experiment or with a theory proven and applied to other phenomena) is not yet verified.

No less important than the words on physics (and astronomy) are Galileo's ideas on the *convergence* of science and faith; both science (immutable) and Sacred Scripture come from the same God. In the letter to Don Benedetto Castelli (dated 27/12/1613) he wrote²³:

Since, therefore, Scripture in many places is not only capable, but necessarily in need of expositions other than the apparent meaning of words, it seems to me that in natural disputes it should be reserved in the *last* place: because, proceeding equally from the divine word, Sacred Scripture and nature, the former as the dictation of the Holy Spirit, and the latter as the *most observant executor of the orders of God*; and being moreover agreed in the Scriptures, in order to accommodate the understanding of the universal, to say many things different, in appearance and as to the meaning of the words, from the absolute truth; but, at the same time, nature being unstoppable and immutable, it cares nothing whether its hidden reasons and modes of operation are or are not exposed to the capacity of men, so that it never transgresses the terms of the laws imposed on it; It seems that the natural effects which either sensible experience places before our eyes or the necessary demonstrations conclude to us, should not be revoked in any account in doubt by places in Scripture which have a different appearance in words, since not every saying of Scripture is bound to obligations as severe as any effect of nature. On the contrary, if for this respect alone, to accommodate the capacity of rude and uncomplicated peoples, Scripture has not refrained from overshadowing its most principal dogmas.

Galileo's "trial"²⁴ has become a flagship case for all anti-ecclesiastic movements. But it is worth checking state of matters in original texts.

²³ G. GALILEI, *Opere*, Biblioteca Treccani and Il Sole 24 ORE, Milan 2006, p. 594.

²⁴ The penalty that Galileo suffered after the trial of 1616 (nb. the signatures of certain judges on the protocol are missing) was to recite seven psalms three times a week; Because of the astronomer's blindness, the psalms could be recited by his daughter, a nun.

7.7. Cartesio: Sensus communis

If in Descartes' time (René Descartes, 1596-1650) there were lawyers of copyright, he would be the richest man in the world: no scientific article, no statistical comparison, no economic forecast can do less than the graph with two orthogonal axes. Mathematics was born in Babylonia and Egypt in the form of geometry, then with Arab, Italian (Fibonacci), French (Viète) mathematicians numerical calculus (algebra) was formed; with Descartes the two branches were reunified.

But Descartes was also a great physicist and first of all a philosopher. In physics, before Newton he formulated the three laws of dynamics – indeed, his third law, on the momentum that bodies lose or acquire in collisions, is clearer than Newton's 3rd law. In optics he explained the rainbow with principles of light refraction. In epistemology, Descartes developed the modern (i.e., Western) analytical model of scientific procedures: not phenomena in their confused complexity, but identifying particular problems and solving them step by step, with conclusive reasoning – yes or no.

Descartes is sometimes associated with materialist philosophy. In one of his last works he asked himself about "primary philosophy", that is, theology. He also asked them questions about the relationship between the human soul and the brain. In particular, he searched, where is *common sense* in the brain, using the terminology of Albert the Great, that is, the functions of reasoning: Descartes had hypothesized that in the amygdala. Recent studies²⁵ indicate that the amygdala is a kind of the control unit of the brain, where not only thoughts but also emotions pass. But common sense is not the soul: the latter is much more complex – it governs the body, but leaves it, when the heat of the body vanishes²⁶.

Perhaps Descartes' most famous saying is: "*Cogito, ergo sum*". His contemporary, Pascal, wrote that man is a thinking reed. Both of them, like the specific human condition, have identified our self-consciousness: the only one in the whole animate world.

The dialogue written around 1641 and published posthumously, *The Search for Truth by Natural Light* begins thus: "Man is not bound

²⁵ L. PESSOA, *The Cognitive-emotional Brain. From Interactions to Integration*. MIT Press, 2013.

²⁶ R. CARTESIO, *Passioni dell'anima*, [Passions of the Soul] Bonpiani, 2003 (first French edition 1649).

to read all the books and learn all that is taught in school; indeed, it would even be a lack of his education because he would not have time to do good deeds that these book teach on."

In the third of the *Metaphysical Meditations*, Descartes speaks of the existence of God²⁷

22. And therefore there remains the only idea of God, in which it must be considered whether there is anything that could not have proceeded from me. By the name of God I mean an infinite, independent, supremely intelligent, supremely powerful substance, from which both I myself and every other thing in existence, if there is anything else, were created. All these things are such that the more diligently I examine them, the less they seem to me to come from me alone. And therefore, on the basis of what has been said before, one must necessarily conclude that God exists.

Descartes was therefore far from atheism. Like another of his compatriots, from the same era of fratricidal wars in Europe, Blaise Pascal.

7.8. Pascal: The immense world

Leonardo da Vinci, Michelangelo, Bramante, Renaissance artists are defined as "universal" men – with very broad interests, from military genius to painting. But in all human history great brains are universal. So was Blaise Pascal (1623-1662). An avid dice player laid the foundations of probability calculus (which, as we know, govern the world of quantum mechanics). A mathematician, philosopher, builder of the first mechanical computer, discoverer of the laws of hydrostatics.

Two of his reflections are famous – on man who is nothing but a thin cane - a thinking reed, and "Pascal's bet" based somewhat on the calculation of probability: given the magnitude of the possible reward in the heavens, even if we cannot have certainty of this prize, it is worth to believe in God. Pascal devoted several of his *Thoughts* to religious matters. In particular, he realized that man stands between the infinitely small and the infinitely large, and that the limits of the universe are not reachable for us:

²⁷ R. DESCARTES, *Metaphysical Meditations*, <http://www.ousia.it/SitoOusia/SitoOusia/TestiDiPhilosophy/TextsPDF/Descartes/DescartesMeditations/MeditazioniMetafisiche.pdf>. [provisional translation]

72. *Disproportion of man*

Let man, therefore, contemplate all nature in its sublime and full majesty; let him turn his sight away from the objects that surround him. You aim for that dazzling light that is placed as an eternal lamp to illuminate the universe; and let the earth appear to him as a point in relation to the vast circle which that star describes, and let him be amazed that that vast circle is but a very small part compared to that described by all the stars that revolve in the firmament²⁸.

But if our sight stops there, the imagination must go further; and it will sooner tire of imagining that nature to give it comes out. This whole visible world is but an imperceptible segment of the wide circle of nature. No idea comes close. We want to inflate our imaginations beyond imaginable spaces; we can only give birth to atoms with respect to the reality of things. It is an infinite sphere in which the center is everywhere and whose circumference is nowhere²⁹. Finally, the greatest sensible character of God's omnipotence is the fact that our imagination is lost in this thought.³⁰

Pascal, the scientist, realized the limitations of knowing God through reasoning – it also serves the heart, that is, the faith.

144. We know the Truth not only with reason, but also with our hearts. In the latter way we know the first principles; and in vain reasoning, which has no part in it, tries to challenge certainty. [...] In fact, the understanding of the first principles—such as the existence of space, time, motion, and numbers—is as solid as any of those procured for us by reasoning. [...]

This impotence must, therefore, serve only to humiliate reason, which would like to judge everything, and not to challenge our certainty, as if reason alone were capable of instructing us. Would to God, that, on the contrary, we would never need it and know everything by instinct and feeling.

That is why those to whom God has given religion by the feeling of the heart are very fortunate and well legitimately persuaded. But to those who do not have it, we can give it only by means of reasoning, waiting for God to give it to them by the feeling of the heart: without which faith is purely human, and useless for salvation."

Pascal also became aware of a kind of "principle of indeterminacy" of our knowing God: those who want to believe find sufficient arguments, those who do not want to believe are not forced to do so. Vitto-

²⁸ In Pascal's time, the Copernican theory was officially banned from the French Academy, not due to any official statements from the Church.

²⁹ Recall that according to modern cosmology we can define neither the center nor the limits of the universe.

³⁰ B. PASCAL, *God or the World. I tratti da Pensieri*, edited by C. Lamparelli, Oscar Mondadori, Milan 2008, p.18. [provisional translation]

rio Messori calls this principle "light-dark." In a "forced" faith, man would not need individual grace.

183. The course of God, who disposes all things gently, lies in introducing religion into the intellect by arguments, and in the heart by grace. Whoever wanted to introduce it into the intellect and heart by force and threats, would not introduce religion but terror, "rather terror than religion."

After Pascal's death, a letter was found sewn into the lining of his garment: "God of Abraham, God of Isaac, God of Jacob, not of philosophers and scholars. Certainty. Certainty, feeling, joy, peace. God of Jesus Christ."³¹ But this declaration of faith is still weak compared to the one published by Newton in the appendix to his revolutionary treatise on physics: *Mathematical Principles of Natural Philosophy*.

7.9. Newton: Omnipotent and Omniscient God

Isaac Newton was one of the undisputed geniuses in the entire history of humanity. Although his interests were not as broad as Aristotle's, his contribution to physics (and mathematics) is comparable only to that of Albert Einstein.

Newton, born on Christmas Day 1643 (the year of Galileo's death) was a semi-orphan (his father died before Isaacus was born). Unable to look after the flock (he read books or made wooden models of mills and carts) he was sent to school and then admitted to Trinity College, Cambridge. In 1667 he won the position of *minor fellow*, promising to study theology and take priestly vows³². In adulthood he worked as the head of the state mint: it was he who invented the grooves on the edge of coins, to avoid shaves of the gold on the circumference (so-called "tangents", in Italian – bribing).

Newton, with his extraordinary ability to observe and deduce, clarified the Copernican system, derived Kepler's laws and predicted the motion of comets. It was he who gave physics – at times of Galileo a mere dialog – the precise mathematical formulation: combining Euclid's geometry, arithmetic and the natural philosophy, as physics was called. But while he gave a mathematical formulation to the law of gravity, he did not explain the *nature* of gravitational interaction.

³¹ *Ibid.*, p. 11.

³² ROB ILIFFE, *Newton. A Very Short Introduction*, Press, 2007, p. 19. Oxford University

Surely for this reason he was criticized. Also Descartes' theory was circulating at that time, attributing the motion of planets to gigantic vortices of invisible matter that pervaded all of space.

Newton's theory of gravity is based on forces acting at a distance, in a cosmic vacuum. Then, to the second edition of the *Mathematical Principles of the Natural Philosophia*, Newton added a footnote, *Scholium Generale*, clarifying that Descartes' theory of vortices is a step backwards compared to Copernicus and Galileo, who did not need any celestial matter. Then, in the same *Scholium*, written in Latin, he makes important clarifications, answering "why all this". In the fourth second paragraph of the *Scholium* Newton summarizes the motion of six planets, the Moon and the comets, concluding in a similar way to Copernicus – on the immensity of the universe and the logic of its construction³³:

This most elegant ensemble of the Sun, planets and comets could not be born without the design of an intelligent and powerful entity. And if the fixed stars are the centers of analogous systems, all these, being built with an identical design, will be subject to the power of the One.³⁴

God is the origin of this cosmic order, but not only the origin. Different philosophies, even modern ones, associate God with nature. Newton answers: no! God is the Lord of the entire universe—he rules over it and sets the laws. God, Newton says in agreement with St. Thomas, is a supreme Being – perfect, omniscient. And also omnipotent – the beginning of all succession, the cause of transition between potency is the act. God does not belong to space or time but he had created this space and time.

He rules all things not as the soul of the world, but as Lord of the universe. And because of his dominion he wants to be called Lord-God, Pantocrator Παντοκράτωρ. For God is a relative word, and refers to servants: a divinity is the lordship [dominatio] of God, not over his own body, as is held by those for whom God is the soul of the world, but over the servants. God is the su-

³³ ISAAC NEWTON, *Mathematical Principles of Natural Philosophy*, edited by A. Pala, UTET, Turin 1965, p. 793-4, [provisional translation]

³⁴ «Elegantissima hæcce solis, planetarum & cometarum compages non nisi consilio & dominio entis intelligentis & potentis oriri potuit. Et si stallæ fixæ sint centra similium systematum, hæc omnia simili consilio constructa suberunt *Unius* dominio: præsertim cum lux fixarum sit ejusdem naturæ ac lux solis, & systemata omnia lucem in omnia invicem distantiam posuerit. Et ne fixarum systemata per gravitatem suam in se mutuo cadant, hic eadem immensam ab invicem distantiam posuerit.» *Ibidem*.

preme eternal, infinite, absolutely perfect being: but an entity without dominion, although perfect, is not the Lord God. [...]

He is eternal and infinite, omnipotent and omniscient, that is, he lasts from eternity to eternity and from the infinite he is present in the infinite: I rule everything and know everything that is or can be. It is not eternity or infinity, but it is eternal and infinite; it is not the duration and the space, but it lasts and is present. It always lasts and is present everywhere, and by always and everywhere it establishes the lasting and the space.³⁵

Newton devoted the last years of his life to theological questions: this interest is not well regarded by his biographers; in fact, a large number of his letters have not yet been published³⁶. Since all physics is based on Newton's laws – of optics, mechanics, thermodynamics – we give below the original Latin version of the most important fragments of the *Scholium*³⁷: all Newton's insistence on the attributes of God (which coincide with those given by St. Thomas and St. Paul, as indicated by Anna Corazza's thesis already cited) constitutes a *personal testimony* of the great scientist.

Unfortunately, these testimonies are questioned, but not by great scientists, but by ordinary people, "of little faith". In February 2018, a well-known professor of physics at the University of York, Tom McLeish wrote³⁸, in the prestigious journal of worldwide circulation "Physics Today" that the conflict between faith and science harms science in the first place, giving the example of Newton himself. One of the readers, visibly a fierce opponent of the faith, commented that all the greats, including Pascal, Leibniz, and Newton, at a certain point "went mad" by devoting themselves to questions of theology. What a strange coincidence! Have the older ones really "gone crazy"? Surprisingly, all of them, in physics, were geniuses.

³⁵ I. NEWTON, *op. cit.*

³⁶ For a detailed treatment of questions of faith and science in Newton's writings, a dissertation by ANNA CORAZZA, *Newton. Uno sguardo scientifico su Dio* (Newton. A scientific look at God), Ca' Foscari University, Venice, 2013, <http://dspace.unive.it/bitstream/handle/10579/4099/817428-1165177.pdf?sequence=2>.

³⁷ *The General Scholium to Isaac Newton's Principia*, 3rd edition (1726) <https://newtonproject.files.wordpress.com/2013/06/newton-general-scholium-1726-latin-text-letter-size1.pdf>

³⁸ T. MCLEISH, *Commentary: Thinking differently about science and religion*, Physics Today, Vol. 71, Issue 2, February 2018. <https://doi.org/10.1063/PT.3.3831>

absolute perfectum: sed ens utcunque perfectum sine dominio non est dominus deus. Dicimus enim deus meus, deus vester, deus *Israelis*, deus deorum, & dominus dominorum: sed non dicimus æternus meus, æternus vester, æternus *Israelis*, æternus deorum; non dicimus infinitus meus, vel perfectus

^b *Pocockus* noster vocem *dei* deducit a voce *Arabica* *du*, (& in casu obliquo *dī*,) quæ dominum significat. Et hoc sensu principes vocantur *dī*, *Psalm.* lxxxiv. 6. & *Joan.* x. 45. Et *Moses* dicitur *deus* fratris *Aaron*, & *deus* regis *Pharaoh* (*Exod.* iv. 16. & vii 1.) Et eodem sensu animæ principum mortuorum olim a gentibus vocabantur *dī*, sed falso propter defectum domini.

meus. Hæ appellationes relationem non habent ad servos. Vox *deus* passim ^b significat dominum: sed omnis dominus non est deus. Dominatio entis spritualis deum constituit, vera verum, summa summum, ficta fictum. Et ex dominatione vera sequitur deum verum esse vivum, intelligentem & potentem; ex reliquis perfectionibus summum esse, vel summe perfectum. Æternus est & infinitus, omnipotens & omnisciens, id est, durat ab æterno in æternum & adest ab infinito in infinitum: omnia regit; & omnia cognoscit, quæ fiunt aut fieri possunt. Non est æternitas & infinitas, sed æternus & infinitus; non est duratio & spatium, sed durat & adest. Durat semper, & adest ubique, & existendo semper & ubique, durationem & spatium

constituit. Cum unaquæque spatii particula sit *semper*, & unumquodque durationis indivisibile momentum *ubique*; certe rerum omnium fabricator ac dominus non erit *nunquam*, *nusquam*. Omnis anima sentiens diversis temporibus, & in diversis sensuum, & motuum organis eadem est persona indivisibilis. Partes dantur successivæ in duratione, coexistentes in spatio, neutræ in persona hominis seu principio ejus cogitante; & multo minus in substantia cogitante dei. Omnis homo, quatenus res sentiens, est unus & idem homo durante vita sua in omnibus & singulis sensuum organis. Deus est unus & idem deus semper & ubique. Omnipræsens est non per *virtutem* solam, sed etiam per *substantiam*: nam virtus sine substantia subsistere non po[529]test. In ipso^c continentur & moventur universa, sed sine mutua passione. Deus nihil patitur ex corporum motibus: illa nullam sentiunt resistantiam ex omnipræsentia dei. Deum summum necessario existere in confesso est: Et eadem necessitate *semper* est & *ubique*. Unde etiam totus est sui similis, totus oculus, totus auris, totus cerebrum, totus brachium, totus vis sentiendi, intelligendi, & agendi, sed more minime humano, more minime corporeo, more nobis prorsus incognito. Ut cæcus non habet ideam colorum, sic nos ideam non habemus modorum, quibus deus sapientissimus sentit & intelligit omnia. Corpore omni & figura corporea prorsus destituitur, ideoque videri non potest, nec audiri, nec tangi, nec sub specie rei alicujus corporei coli debet. Ideas habemus attributorum ejus, sed quid sit rei alicujus substantia minime cognoscimus. Videmus tantum corporum figuras & colores, audimus tantum sonos, tangimus tantum superficies externas, olfacimus odores solos, & gustamus sapes: intimas substantias nullo sensu, nulla actione reflexa cognoscimus; & multo minus ideam habemus substantiæ dei. Hunc cognoscimus solummodo per proprietates ejus & attributa, & per sapientissimas & optimas rerum structuras & causas finales, & admiramur ob perfectiones; veneramur autem & colimus ob dominum. Colimus enim ut servi, & deus sine dominio, providentia, & causis finalibus nihil aliud est quam fatum & natura. A cæca necessitate metaphysica,

^c Ita sentiebant veteres, ut *Pythagoras* apud *Ciceronem*, de *Natura* deorum, *lib.* 1. *Thales*, *Anaxagoras*, *Virgilius* *Georgic. lib.* iv. v. 220, & *Æneid. lib.* 6. v. 721. *Philo* *Allegor. lib.* 1. sub initio. *Aratus* in *Phænomen.* sub initio. Ita etiam scriptores sacri ut *Paulus* in *Act.* xvii. 27, 28. *Johannes* in *Evang.* xiv. 2. *Moses* in *Deut.* iv. 39, & x. 14. *David* *Psal.* cxxxix. 7, 8, 9. *Solomon* 1 *Reg.* viii. 27. *Job* xxii. 12, 13, 14. *Jeremias* xxiii. 23, 24. Fingebant autem idolatræ solem, lunam, & astra, animas hominum & alias mundi partes esse partes dei summi & ideo colendas sed falso.

Fig. 7.3. Reproduction of the second page of the *General Scholium* in the third edition of Newton's *Principles*. SOURCE: newton projectca.files.wordpress.com

Today, three hundred years after the *Scholium*, we still do not know what is the cause of the force of gravity that acts at infinite distances and holds the world together. One could say: the exchange of gravitons, i.e. (mysterious) elementary particles, or the curvature of space-

time, according to Einstein's equation – but this only shifts the question. What's more, we don't know what dark matter is, four times more than visible matter, which prevents galaxies from "dismembering" under centrifugal force. Even more: we don't know what dark energy is, four times more than dark matter, which prevents the entire universe from collapsing in on itself due to gravity. We can only repeat after Albert Einstein: "Subtle is the Lord".

7.10. Laplace: Clock Universe

The declarations of Copernicus, Galileo and Newton, on the great plan of God that we find in the mathematical order of nature should serve to strengthen faith. But in some cases it was not so: God who designed the world, perhaps, is no longer interested in his work. Once the world has started, like a perfect clock, does it go on its own? The common stereotype (*a common belief*, as Stephen Snobelen calls it³⁹) attributes this opinion to Newton, but we have shown above, that it is a simplification, which does not correspond to the contents of *Principia*. It was the French physicist and mathematician, Pierre-Simon de la Place, who told Napoleon that he did not need the hypothesis called God.

Marquis Laplace (1749-1827) was first a supporter of the Revolution and then of the absolute monarchy. He made important contributions to celestial mechanics, mathematics and theoretical physics.

The statement attributed to Laplace is: "Give me the initial conditions and I can predict the fate of the whole world". A similarly absurd saying like that of Archimedes about the point of support and the lever that will move the earth. The Archimedes lever should have the length comparable to the Earth-Moon distance, not to mention the support point, which should be heavier than the Jupiter. Laplace's initial conditions mean the positions and velocities (both vectors with three coordinates) of all atoms in the universe. Where do we want to record these positions in order to perform the calculations? On all atoms of the other universe? We are also unable to identify the bodies that wander in the solar system: the millions of asteroids, of which the first, Ceres, was discovered by a Sicilian priest, the same age as Laplace, Giuseppe Piazzi.

³⁹ S. D. SNOBELEN, *The Theology of Isaac Newton's Principia Mathematica: A Preliminary Survey*. Neue Zeitr. Systematische Theologie und Religionphilosophie, Jan.2010, 377.

In truth, not even Laplace can be judged as a-theo. His father wanted him to become a priest, but his mathematical talent prevailed. The literary reproduction of his saying about the determinism of the world does not say "we" may know but "*Une intelligence qui*" – which could be the same superior intelligence that Thomas spoke of in his third "way". Napoleon's question was not whether God exists, but whether God occasionally intervenes in the machine of the universe (*l'intervention de Dieu pour raccommoder de temps en temps la machine du monde*⁴⁰). Laplace's answer was "I don't need such a supposition". God is not a watchmaker.

The whole universe could go like clockwork, but we never know in which direction. The daily experience, but only those who want to see it, show that God is interested in his work, minute by minute: perhaps not in the motion of atoms and planets, because these are not very complex, and are described by *simple equations*, but in man, that is, *his* most complete creature, the most sensitive and therefore also the most fragile. A creature, which also needs divine grace to reason, as another "atheist" of the *common belief*, namely Immanuel Kant, wrote.

7.11. Kant: The starry sky

In the texts of theology and philosophy⁴¹, Immanuel Kant is associated with his refutation of "proofs" of the existence of God, as elaborated, for example, by St. Thomas. As with other thinkers, also in the case of Kant it is also worthwhile to consult his original texts. But before placing Kant (and then also Einstein) in the science-faith ↔ framework we need a personal parenthesis.

My first degree was in economics, which included politics. It was the end of the seventies, when in Poland the so-called socialist system was shattering, more for economic insufficiency than for political reasons. Studying Marx (and Lenin) I learned little. Far more instructive was the unfolding of events during this fall. The repeated, reasoned but unsuccessful attempts to reform the communist system of Soviet origin have made me understand that the individual man is always inserted in his historical, cultural and religious environment. In this environment, an individual contributes to the progress of all humanity,

⁴⁰ https://fr.wikipedia.org/wiki/Pierre-Simon_de_Laplace, cited work - Hervé Faye, 1884.

⁴¹ G. SAMEK LODOVICI, *Existence of God*, Quaderni del Timone, 2004.

but his imprint, and even more his limitations, are determined by his space-time environment. This note concerns everyone – from the pre-Christian Aristotle to the very modern Albert Einstein.

Kant had a university chair in Königsberg, which in the time of Copernicus separated from the Polish Kingdom, since the Teutonic Order converted to the Protestant religion. In the time of Kant, the Empire of Prussia gained, in the course of the Napoleonic wars, its identity and importance, even the religious one, given that for example the Bavarian Prince was Catholic.

Working often in America, England, Korea, I have great esteem for the Protestant religion, especially for its tireless strength in bringing the message of Christ to all peoples. But returning to Kant, behind any French philosopher, whether it be Descartes, Pascal or Laplace, there is the so-called Magisterium of the Church. When it is lacking, reason must, of necessity, dominate faith, despite the fact that faith remains present. Therefore, Kant's reasoning is so important.

So, we must also evaluate Kant's three refutations – of cosmological proof and physical proof, in *the Critique of Pure Reason*. He was Immanuel, who in his pre-philosophical work (in 1772) launched the hypothesis of the formation of the Solar System from a disk of gas (not yet knowing that planetary nebulae are precisely the evidence of similar systems). It was also he who brought thermodynamic proof, that is, of the thermal death of the universe (in accordance with Aristotle's "corroding" time) for the Creation.

But on the subject of the existence of God, Kant is called upon with his three arguments on the impossibility of *proving* the existence of God through "pure reason". Simplifying a lot, the two proofs examined, i.e. the ontological and cosmological, can be traced back to St. Thomas' reasoning on the maximum being and on the prime mover of the mutations (not only motion) of the world. Kant, with his rigor of rationality, exploiting his categories of "synthetic" and "analogous" judgments, shows that the two "proofs", if we consider them to be "proofs", are mere suppositions.

The fifth way of St. Thomas is called by Kant "the physical-cosmological proof"; it also cannot be categorized in the rigid schemes of precise reasoning. But the introduction to the question reads as follows:

The present world opens up such an immense theater of variety, order, *finality*, and beauty, whether it is pursued in the infinity of space, in its limitless division, that, even after the knowledge that our weak intellect has been able to acquire of it, every language, to so many and incalculably great wonders, loses its energy, all numbers their capacity for measurement, and our own thoughts all limitations, so that our judgment of the whole must resolve itself into a mute, but precisely for this reason all the more eloquent *amazement*. On the other hand, we see a *chain* of effects and causes, *of ends* and means, regularities in birth and perishing; and since nothing has come of itself in the state in which it is, this refers further and further to another thing as its cause; which, in its turn, makes precisely the search itself necessary. so that in this way the whole universe would have to sink into the *abyss of nothingness*, if something were not admitted which, outside this infinite contingent, subsisting for itself originally and independently, sustains this contingent and at the same time, as the cause of its origin, ensures its duration. This *supreme cause* (with respect to all the causes of the world in all its contents, much less do we know how to calculate its *magnitude* of comparison with all that is possible. But what prevents us, since by causality we need an ultimate and supreme Being, to place him together, by degree of perfection, above all other possible beings?⁴² (GK underline)

We have already discussed in the scientific part that without the continuous succession of events, without the forces that are still mixed with us today, the entire universe would have sunk into nothingness in a quarrel: Kant arrived at the same conclusion by way of pure reasoning. In Kant's passage (by the philosopher) both the fifth way of St. Thomas (by the theologian) and the amazement of Copernicus (by the astronomer) resonate. Obviously, all this cannot be by chance: there are different routes but the same point of arrival. As St. John Paul II emphasized in the encyclical "Faith and Reason": Truth is only one.

Obviously, Kant could not make extensive references to Thomas, doctor and saint of the Catholic Church, but Immanuel's brilliant mind also contributed to a "concordat" between science and faith. One of his last works, *Religion within the Limits of Pure Reason*, was banned by the censorship of the Kingdom of Prussia, as it was not orthodox enough with the governing religion. On divine grace Kant wrote as follows:

⁴² I. KANT, *Critique of Pure Reason*, II edition, Riga, 1787, http://www.unife.it/lettere-philosophy/filo.edu/insegnamenti/storia_filosofia/materiale-didattico/a.a.-2010-2011/Kant-critica-della-ragion-pura.pdf, p. 395. [provisional translation]

Whatever good man is capable of doing in accordance with the principles of liberty may be called Nature, in contrast to the good that flows from pre-eternal help, called Grace. That last epithet does not, however, signify a physical property other than Freedom; it is used because we know that it is subject to the laws of causality, while it also happens that the former lead to orderly sequences in physical systems, Reason possesses a simple and visible compass for guidance: and instead touching any effect of Grace we remain left in the shadows; with Reason being completely ignorant of the laws of this operation. In fact, everything that is the supra-physical avoids the gaze of our knowledge, and among them are transcendental points of cognition classified as Morality, or absolute Holiness.⁴³

And also in the passage of the *Critique of Pure Reason* (p. 393) Kant emphasizes that scientific "proofs" are not possible, but only a humble faith, which does not claim to be approved by all and supported by grace (GK underlines):

But, although we have nothing to oppose to the rationality and usefulness of this procedure, which on the contrary we have rather to recommend and encourage, we cannot for this reason approve the claims that this kind of proof could make to an *apodictic certainty* and to an *adhesion* not needy point of *grace* and *external* support; nor can it in any way be detrimental to the good cause to lower the *dogmatic* language of a bold argument to the point of moderation and discretion proper to a *faith sufficient for peace*, even if an unconditional submission is not imposing .

Taking into account the difficulties of translation (and Kant's specific literary style), the quoted fragment reflects Pascal's aforementioned opinion, that the cognition of mysteries of Faith occurs with both Reason and Grace.

Kant's most famous words are those written on his tomb: "The starry sky above me and the moral law within me."

7.12. A shady part

As the English version of the Wikipedia, now more detailed than the renowned *British Encyclopedia*, describes Kant has had "a major influence on contemporary philosophy, particularly in the fields of metaphysics, epistemology, ethics, political theory and aesthetics". The same voice *Immanuel_Kant* says that "the exact nature of Kant's reli-

⁴³ I. KANT, *Religion within the boundary of pure reason*, transl. J.W. Semple, ed. Clark, Edinburgh, 1838, p. 272 <https://archive.org/details/religionwithinb00kantgoog/page/n271>.

gious ideas continues to be the subject of philosophical dispute, with views ranging from the impression that he was initially the advocate of atheism who at some point had developed an ontological argument for God, to the more critical view that Nietzsche had epithetized as 'theological blood' and was only a sophisticated apologist for the traditional Christian faith."

The fact is that Kant's philosophy is also evoked by the interpretations that removed God from the universe. Early in the course of history it has become apparent that these ideologies have shown the greatest contempt for Man ever seen in the entire course of mankind. For this reason we leave these names absent.



Fig. 7.4. "Real socialism" (and other atheistic ideologies) has led to a contempt for Man never seen in the course of history. On the monument in front of the Gdansk shipyards (where the "Solidarity" trade union was born, on the photo), and dedicated to the fallen workers, the poet, Nobel Prize winner, Czesław Miłosz wrote: "You, who struck a poor man, bursting with laughter on his misfortune, do not be sure: the poet remembers! Words and deeds will be written" and in addition the words of the psalmist: "The Lord will give strength to his people; the Lord will give them the blessing of peace". PHOTO: T. WIERZEJSKI.

7.13. Darwin: The Breath of Life

Charles Darwin's name is often used as a banner of materialism. In fact, in one of his late letters, when asked insistently about his position, he replied that he felt atheist. But a careful reading of his biography does not confirm this. It is necessary to distinguish those who

are atheists, that is, those who do not admit the existence of God, from those who *have no doubts* about the existence of God, but use the reason to discover His nature.

In Darwin's autobiography we find the same words used by Newton in the *Scholium* about the benevolent God, creator of the immense and wonderful universe, God omnipotent and omniscient with respect to our limited minds⁴⁴.

A being so powerful and so full of knowledge as a God who could create the universe, is to our finite minds omnipotent and omniscient, and it revolts our understanding to suppose that his benevolence is not unbounded, for what advantage can there be in the sufferings of millions of the lower animals throughout almost endless time? This very old argument from the existence of suffering against the existence of an intelligent first cause seems to me a strong one; whereas, as just remarked, the presence of much suffering agrees well with the view that all organic beings have been developed through variation and natural selection.

Darwin, in his autobiography, used the terms "first cause" and "immortal soul": like Pascal and Einstein he was amazed at man's ability and willingness to look far and into the future: "When I reflect in this way, I feel obliged to seek the First Cause that has the intelligent mind in some analogous way like man: then I deserve to be called a theist".

Formerly I was led by feelings such as those just referred to, (although I do not think that the religious sentiment was ever strongly developed in me), to the firm conviction of the existence of God, and of the immortality of the soul.⁴⁵

Another source of conviction in the existence of God, connected with the reason and not with the feelings, impresses me as having much more weight. This follows from the extreme difficulty or rather impossibility of conceiving this immense and wonderful universe, including man with his capacity of looking far backwards and far into futurity, as the result of blind chance or necessity. When thus reflecting I feel compelled to look to a First Cause having an intelligent mind in some degree analogous to that of man; and I deserve to be called a Theist.⁴⁶

As in the soul of every man (and as in the evaluation of any phenomenon), different points of view are intertwined. It is wrong to attribute it to Darwin, who (perhaps unintentionally) unleashed materi-

⁴⁴ CH. DARWIN, *Autobiografia*, ed. Nora Barrow, Collins, London 1958, p. 90.

⁴⁵ *Ibidem*, p. 94.

⁴⁶ *Ibidem*, p. 93.

alism in biology, a personal atheistic view of the world. Nor can Darwin be called a "creationist".

He himself concludes the *Origin of Species* with words that seem to be copied from Genesis:

There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.⁴⁷

7.14. Einstein: The most difficult thing

Einstein, after having written "at the table" (i.e. without using experimental indications) the equations that govern the entire universe, wondered about our, that is, human, cognitive capacities. He said, "The hardest thing in the universe to understand is that we can understand it."

Of Albert Einstein it must be emphasized that his youth was not without some difficulties. Born in 1879 in Ulm, in the Kingdom of Bavaria which had become part of the Prussian Empire few years earlier. His father, "not much practicing Israelite", owned a small factory of electrical equipment. Given the economic difficulties, the father moved to Pavia, leaving his son at high school in Munich. Albert dropped out of school, but was unable to obtain his baccalaureate in Italy. Against his father's wishes, he enrolled in Physics and not in Electrical Engineering. In addition, he fell in love with a Serbian refugee in Switzerland, Mileva, with whom he had a daughter. Only after the death of his father, Albert managed to marry, obtained a position as a clerk in Bern (the academic seat he was hoping was assigned to another colleague), acquired Swiss citizenship and became the father of two boys. In one year, 1905, he wrote four articles that revolutionized the whole, contemporary, our world.

Albert Einstein was a believer, even if strongly conditioned by his cultural roots: he did not accept "human interference" in religion.

⁴⁷ Last words of *Origin of Species*, 1st Edition, Charles Darwin (1859), on-line: <http://www.fossilmuseum.net/>.

Consequently, he professed a kind of "cosmic religion," based on individual wisdom and human responsibility.

"Already in the first stages of the evolution of religion (for example, in several psalms of David and some Prophets), the first beginnings of cosmic religion are found; but the elements of this religion are strongest in Buddhism, as we have learned in particular in the admirable writings of Schopenhauer" (*How I See the World*⁴⁸, p. 25)

We see in Einstein's position the similar psychological constraints that Kant showed – of religion acquired at birth or "provided" by the state – but at the same time we see a clear declaration of faith in God. Faith is indispensable not only for a nation, but first of all to give meaning to life to each individual. Life without faith means an inability to live, says Einstein.

Meaning of life

What is the meaning of our existence, what is the meaning of the existence of all living beings in general? To be able to answer such a question is to have religious feelings. You will say: but it makes sense to ask this question. I answer you: anyone who believes that his life and that of his fellows is meaningless is *not only unhappy, but scarcely capable of living*.

Cosmic Religion

The most beautiful feeling is the mysterious side of life. It is the deep-seated feeling that is always found in the cradle of art and pure science. Anyone who is no longer able to feel either amazement or surprise is dead, so to speak; *His eyes are dull*. The impression of the mysterious, even if mixed with fear, has aroused, among other things, religion. To know that there is something *impenetrable*, to know the manifestations *of the deepest intellect* and the *most luminous beauty*, which are accessible to our reason under the most primitive forms, this consciousness and this feeling, this is true devotion: in this sense, and in this sense alone, *I am among the most profoundly religious men*. (p. 22, GK underline)

Einstein, like his compatriot of the same period, Max Planck, distinguishes faith from the different forms of religions, all based on our image. But God resides in the whole cosmos; we add: we find the mind of God also in the mathematical beauty of the equations discovered by Albert.

⁴⁸ A. EINSTEIN, *Come io vedo il mondo*, trans. R. Valori, Newton Compton Editori, Rome 1975. [*provisional translations from Italian to English]

Gods in human form

All these religions, however, have one common point, which is the anthropomorphic character of the idea of God: beyond this level there are only particularly noble individuals. But in any case there is still a third degree of religious life, although it is very rare in its pure expression, which is that of cosmic religiosity. It cannot be fully understood by those who do not feel it because no idea of anthropomorphic God corresponds to it. (p. 25)

Let us conclude with Albert's assertion that scientists are profoundly religious – not only in his own time, but it seems that he always was: "It is not without reason that a contemporary author has said that in our age, which is generally devoted to materialism, scientists are the only profoundly religious men." (p. 28)

7.15. Planck: A world without religion would be the end

Kant, at the time of the Revolution and the Napoleonic wars, proposed global peace among peoples, Einstein a few days before the explosion of mutual declarations of war (in July 1914) circulated a pacifist manifesto at the University of Berlin (signed only by another colleague). But it was the founder of quantum mechanics, Max Planck, who lived through the hardest times and suffered personal tragedies (one son died in the First World War, another was executed in 1944 when the last trial to remove the dictator failed). And it was Max Planck who became the icon of post-war science in Germany (lending his name to the national research institution): not only for his scientific discoveries, but first and foremost for having shown his iron faith in humanity's darkest era.

It was Planck's lecture on Thursday, December 14, 1900, in Berlin that began the era of modern physics. Lord Kelvin still a few years earlier maintained that twentieth-century physics will have the sole task of perfecting the precision of previous physics: as it was discovered immediately later – nothing more wrong. Quantum mechanics and Einstein relativity have shown that classical physics is only an approximation of the real world: it does not hold on micro neither on cosmic scales. In the mid XXth century, also Maxwell's electromagnetism has been for quantum phenomena. Today, we physicists know, from experience, that "God's plan is impossible to understand with our

limited mind", as Kant said. But Planck was not only the scientist, but also the philosopher of science⁴⁹.

Max Planck, at the height of Nazism (in May 1937, after the "Anschluß" in Austria) gave a public lecture entitled "Religion and the Natural Sciences", explaining among other topics the recent discoveries in physics. But the most significant are his judgments on the importance of faith, both for the individual man and for entire societies. For Planck, Religion is in bond, a union, a dripping of Man to God. «Religion ist die Bindung des Menschen an Gott». Religion is indeed man's private "thing", but it is equally important for society, indeed, the whole of humanity. And God is eternal and omnipresent, as he was for St. Thomas, Newton and Kant.

Not only does each man have his own religion, but religion has a value and importance for a larger community, for a people, for a race, and in the same way for the whole of humanity.

A believing man finds the answer to the question whether God exists, before man appeared on earth, that it is He who holds the whole world from eternity, believers and non-believers, in His almighty hand, and that He is unchangeable on His inaccessible throne, and will be, even when the earth with all that it contains, no longer exists."⁵⁰

In the book printed in 1932 in the United States *Where Science Goes* Planck discusses both scientific progress and philosophical questions, especially the principle of causality, determinism and the free will of man. In the middle of the volume (p. 168) Max Planck affirms the importance of religion for man, for society, and also for science:

But man needs fundamental indications to lead his daily existence, and this need is much more pressing than the hunger for scientific knowledge. A sin-

⁴⁹ For a concise and interdisciplinary biography of Max Planck, we recommend *Planck. Quantum theory. The revolution of the infinitely small*, by A.T. PÉREZ IZQUIERDO, RBA, Milan 2014.

⁵⁰ «Nicht etwa hat jeder Mensch seine eigene Religion, vielmehr beansprucht die Religion Gültigkeit und Bedeutung für eine größere Gemeinschaft, für ein Volk, für eine Rasse, ja in letzter Linie für die gesamte Menschheit. [...] Der religiöse Mensch beantwortet die Frage dahin, daß Gott existiert, ehe es überhaupt Menschen auf der Erde gab, daß er von Ewigkeit her die ganze Welt, Gläubige und Ungläubige, in seiner allmächtigen Hand hält und daß er auf seiner aller menschlichen Fassungskraft unzugänglichen Höhe unveränderlich thronen bleibt, auch wenn die Erde mit allem, was auf ihr ist, längst in Trümmer gegangen sein wird.» M. PLANCK, *Religion und Naturwissenschaft*, Vortrag gehalten im Baltikum (Mai 1937), p. 8. <https://psychomedizin.com/medien/pdf/max-planck.pdf>.

gle action is often far more meaningful to a human being than all the wisdom in the world put together. [...]

Religion belongs to reality that is inviolable in the face of the law of causality and for this reason it remains close to science. The scientist must recognize the value of religion in itself [...]. I think most scientists will agree and raise their hands against religious nihilism as destructive to science as well.

There can never be a real opposition between science and religion: because one is a complement to the other. Every serious and thoughtful person realizes, I think, that the religious element in his nature must be recognized and cultivated if all the capacities of the human soul were to act together in perfect balance and harmony. And, indeed, it is not by chance that the greatest thinkers in all ages were also deeply religious souls, even if they did not publicly show their religious feelings."⁵¹

But was religion, or rather – the abuse of the name of God (as Roberto Begnini says in his memorable television monologue *The Decalogue*) the cause of bloody conflicts? Yes, but the lack of faith in society is an even worse evil. Planck, in his 1937 speech, after explaining the importance of religion and the contribution (not contradictory to it) of modern physics, lashes out against dogmatism, atheism, superstition – which come when faith is lacking.

The concluding words of the founder of modern physics, Max Planck, are a kind of manifesto: "In an endless war against skepticism and dogmatism, against bad faith and superstition, religion and science act together, and the watchword in this struggle is and will always be the same: Go to God!"⁵²

7.16. Barrow & Tipler: The Anthropic principle

The anthropic principle is a philosophical (and scientific) formulation of marveling at the existence of the universe and our place in it. It is the amazement that we have read in the works of St. Thomas, Copernicus, Pascal and Darwin. It is a strange "coincidence" between the

⁵¹ M. PLANCK, *Where Science Is Going?* W. W. Norton, New York 1932. https://archive.org/stream/whereissciencego00plan_0#page/2/mode/2up, vedi anche: M. PLANCK, *The Universe in the Light of Modern Physics*, G. Allen & Unwin, London 1931, <https://archive.org/details/universeinthelig032967mbp/page/n9>.

⁵² «Es ist der stetig fortgesetzte, nie erlahmende Kampf gegen Skeptizismus und Genge Dogmatismus, gegen Unglaube und gegen Aberglaube, den Religion und Naturwissenschaft gemeinsam führen, und das richtungweisende Lösungswort in diesem Kampf lautet von jeher und in alle Zukunft: Hin zu Gott!» M. PLANCK, *Religion und Naturwissenschaft*, *op. cit.*

laws of cosmology, physics, chemistry and biology that we "settle" into this external world.

The book entitled "The Anthropic Principle" published in 1986 by two prominent theoretical physicists, John Barrow and Frank Tipler, constitutes a scientific basis for the modern understanding of man's place in the universe. Starting from the philosophical tradition (Aristotle, St. Thomas), the authors embark on a very detailed path of physics (and very difficult for non-experts)

The topics brought range from nuclear physics, atomic physics, cosmology, chemistry. First, Barrow and Tipler calculate the age of the universe right to have the abundance of carbon. As we have mentioned, carbon with its four electrons ("valence") allows the construction of almost an infinite number of organic compounds, which in turn can perform many different biological functions. But the chemical and nuclear characteristics of carbon belong to two branches of science that are not "coordinated" at all. It seems that by "pure chance" carbon is synthesized in abundance in stars, which however cannot be too young (in those only helium is synthesized) nor too old, full of iron.

Thus, from a simple mathematical formula that contains the mass of the proton, the gravitational constant, Planck's constant and the speed of light (Barrow, Tipler, p. 42), we obtain the age of the universe "hostable" for life – which is about 10 billion years: exactly the age of "our" Universe.

However, to synthesize carbon inside stars, a cluster of stellar matter is not enough – special processes are also needed: carbon (nuclear mass 12) is equivalent to three helium nuclei (mass 4). Three-body collisions are extremely unlikely. But "nature" has invented a transitional state – a beryllium core (mass 8) that by "coincidence" lives long enough (and has appropriate energy levels) to allow carbon synthesis.

Barrow and Tipler's book, certainly one of the most important after Copernicus, is full of physical formulas and descriptions of processes, which all together form an anthropic principle – not philosophical or theological but scientifically argued (not "proven" because this would go against Pascal and already quoted Messori's principle of "chiaroscuro" – light and shadow).

Barrow and Tipler also formulated their Ultimate Anthropic Principle, as well as the well-identified weak principle (the Uni-verse is

made so that *the appearance of man* was possible⁵³) and the strong principle⁵⁴ (the Universe is made so *to allow* the appearance of man). The ultimate anthropic principle (PAU) says that the appearance of man changes the fate of the Universe forever.

"Ultimate anthropic principle: Intelligent information processing must necessarily develop in the universe, and once it has appeared it will never die out." (p. 47)

Giancarlo Cavallieri writes in "Timone", an Italian review of information and apologetics, in an article "The universe? It is designed on a human scale"⁵⁵: "The physical theory of the anthropic principle shows that the values of the fundamental physical constants are the only ones that allow the life and origin of man and require the existence of a Designer. Alternative theories run into absurdities."

Barrow and Tipler, being two scientists, have to stay a little more "on the sidelines". They specify:

It seems appropriate to repeat that both the PAU and the PAF are mere conjectures: neither of them should be considered as a well-established physical principle. On the contrary, the PAD is a reformulation, albeit in a more subtle form, of one of the most important and consolidated scientific principles: it is important to take into account the limitations of one's own measuring apparatus when evaluating the results of one's observations. (p. 48)

Claims about any formulation of the anthropic principle require a very broad and deep scientific, interdisciplinary basis. However, with the accumulation of new evidence, the topic is taken up again, not only in philosophical theses, but in strictly scientific journals. A recent example is a review paper published by Luke Barnes, a physicist and astronomer at the prestigious ETH Zurich and the University of Sydney.

⁵³ "Weak anthropic principle: Observed values of any physical and cosmological magnitude are not all equally likely, but they are subject to the restriction that there are places where carbon-based life can evolve and that the universe is old enough for this to have already happened." J.D. BARROW, F.J. TIPLER, *The Anthropic Principle*, Adelphi Edizioni, Milan 2002, p. 40. [provisional translation from Italian]

⁵⁴ 'Strong anthropic principle: The universe must have those properties which allow the development of life within it, at some stage of its history', *Ibid.*, p. 46.

⁵⁵ G. CAVALLIERI, *L'universo? It is designed on a human scale*, «Il Timone», May 2004, p. 50-51.

A graph, reported in that article (and cited on several inter-net sites⁵⁶), shows a very narrow range of atomic constants that uniquely allow the existence of our universe. By varying a little the ratio of the mass of the proton with respect to that of the electron (which amounts to 1837 in our universe) and the electrostatic force of two electrons ($1/137$ in units of $\hbar c$) we enter the areas of "impossibility": the existence of atoms or the existence of stars, or the existence of ordered (i.e. biological) structures, becomes impossible.

The condition for the existence of planetary systems around stars places further limits on the two physical constants. All in all, the atomic stability graph still does not take into account the cosmological constants: the force of gravity and the speed of expansion of the universe (i.e. dark energy). Physicists still do not know how to answer how cosmological constants are linked to atomic ones.

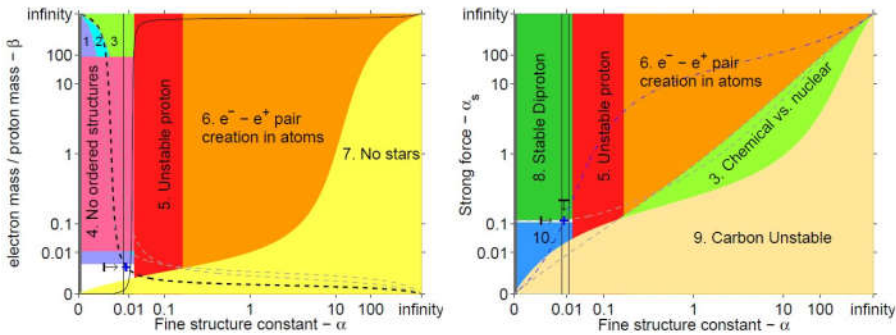


Fig. 7.5. The physical coordinates of possible universes (different colors) and the "habitable", i.e. "anthropogenic" (white) zones. (a) The coordinates of atomic physics – the mass of proton and electron vs. the force of their interaction: yellow – there are no stars, ascar-ncion – there are no atoms, red – there is no proton etc. (b) The coordinates of nuclear physics – the force of interaction between neutron and proton vs. the electromagnetic force (simplifying): beige – there is no cabonium, green – no helium is formed, etc. SOURCE: L.A. BARNES "The Fine-Tuning of the Universe for Intelligent Life", Astronomical Society of Australia, 29 (2012) 529-564.

⁵⁶ For example: <https://crossexamined.org/fine-tuning-particles-support-life>, the graph is from L.A. BARNES' article "The Fine-Tuning of the Universe for Intelligent Life", Astronomical Society of Australia, 29 (2012) 529-564, <https://arxiv.org/pdf/1112.4647.pdf>. That article brings other "coincidences" that allowed intelligent life in the Universe.

Antonino Zichichi⁵⁷, nuclear physicist, former director of CERN, uses another language to describe "anthropogenic" physics – to explain the difference between the electric field (which binds electrons and protons in an atom) and fields inside the proton.

This is where the One who made the world intervenes. A proton consists of three particles, called quarks. These are glued to a type of force that is radically different from the electromagnetic one. The force between electrically charged particles decreases as the square of the distance between the electric charges increases. The force acting between quarks does not decrease, it increases as the distance between quarks increases. When quarks are at a distance of one-tenth of a thousandth of a billionth of a centimeter, the force of attraction between quarks becomes enormous (almost infinite). This is a property of *non-abelian*⁵⁸ forces. If atoms and molecules were bound by *non-abelian* forces, a stone hit with a hammer could not break. Nor could tomato sauce exist, since this sauce is the result of the breaking of atomic-molecular bonds. Fortunately, He who made the world gave the Electromechanical Forces abelian properties. This is why there are colors, flavors, touch, taste, smell, sight. And it gave quarks and gluons *non-abelian* properties. And that's why protons and neutrons are highly compact matter: exactly as we need it to be as we are. (p.62)

The book of *Genesis* recounts not only the events that took place but also their evaluation: "And God saw that it was good." Existence (ontology) is linked to moral will (ethics). Tippler and Barrow, the physicist and the mathematician make a similar comment:

The PAU is a statement about the physical world and for this very reason has no ethical or moral content. However, it is closely linked to moral values, since its validity constitutes the physical precondition for these values to arise and remain in the universe: in a universe devoid of life no moral value could exist. The PAU also seems to imply a better cosmos. (p.47)

In the course of their entire work, the two scientists make no specific reference to religion (except for discussion at the philosophical level), but the last sentence of the quote above has clear Christian connotations. *The Anthropic Principle* is an extremely difficult book. But it constitutes a milestone, which encompasses our present scientific knowledge, discussed in a broad philosophical context.

⁵⁷ A. ZICHICHI, *Why I believe in Him who made the world. Between Faith and Science*. il Saggiatore, Milan 1999.

⁵⁸ Zichichi uses the adjective that refers to mathematical properties rather than physical properties. A non-abelian group is made up of mathematical operations whose order cannot be changed.

7.17. Davies: God and the New Physics

Appealing to God in a book on physics undoubtedly widens the circle of possible intrigued readers. So we have several titles that invoke God: "God and the New Physics" by the English scientist Paul Davies, *Why I believe in Him who created the earth and the heavens* by the Italian nuclear physicist Antonino Zichichi, *Understanding the Bible with Physics*, by the New Zealander Stedman⁵⁹ and many others⁶⁰.

As the reader also sees from this text, it is very difficult to write a book that seriously explains both the problems of science and those of philosophy. It is equally difficult to separate and/or combine faith and scientific work in private and professional life.

Ian Barbour in his book *The Ways of Relationship between Science and Religion*⁶¹ listed four possible relationships between science and religion: i) conflict, ii) comparison, iii) parallelism, iv) synergy.

But this list misses the possible nuances of relationships that a single scientist develops under his or her skullcap. Undoubtedly, as already shown, Copernicus, Galileo, and Newton, the founders of physics as a scientific discipline were men of deep, sincere faith. They were aware that superficial reading of their treatises could cause a damage to Christian dogma.

But starting from the Enlightenment it was not like this: many scientists and philosophers, often without clearly declared reasons, fought against the Church. Voltaire's "Il Candido", which tells of Jesuits and cannibals, is a striking example. Thus, towards the end of the eighteenth century, a line of philosophers (and scientists) declared themselves, some more and some less, antagonists of the faith. Their attitude is clearly understood from the way they write.

Paul Davies, who never declared himself a non-believer (but neither did he declare himself a believer), puts faith in a ridiculous light on the question of the beginning of the world: "The idea of a creator

⁵⁹ GEOFFREY ERNEST STEDMAN, "An Orthodox Understanding of the Bible with Physical Science", Eloquent Books, Durham 2012.

⁶⁰ Other titles, such as "The Physics of God: Unifying Quantum Physics, Consciousness, M-Theory, Heaven, Neuroscience and Transcendence" by J. SELBIE (2017) are even more fascinating. Unfortunately, the charm of the title does not always coincide with the precision of the narration.

⁶¹ I. BARBOUR, *Ways of Relating Science and Religion*, in: I. Barbour, *Religion in an Age of Science*, Harper, San Francisco, 1990; for a broad discussion see also MARIANO ARTIGAS, *La mente del Universo*, Fundacion Universitaria de Navarra, Navarra 1998.

God who by an act of will made the universe exist is deeply rooted in Judeo-Christian culture. But it has been seen that this conviction poses more problems than it solves, as is shown by the centuries-old controversies of theologians." (p. 69)

On similar positions was recently passed away Stephen Hawking: he declared that (his) physics does not need God. From this conviction comes the research, outside the Galilean methodology of science (which can be experimental or theoretical, but always verifiable) on parallel universes, on a Big Crunch (the end of the universe in an implosion), on the existence of the world before the Big Bang, etc. None of these inventions were verified – indeed, the universe will expand for at least another hundreds of billions of years, the Big Bang is positioned with great certainty at 13.78 billion years ago, etc., see chapter 2.10. From the point of view of the experimental physicist, and using Ockham's razor – Big Crunch, parallel universes etc. simply do not exist, because there is no recipe, how to verify them experimentally. "The experiment is the conclusive proof of any theory" – used to say Einstein.

The style of many scientific "popularizers" follows a similar paradigm: we present a complex set of scientific facts, the less intuitive ones, we add some names of scientists, not necessarily in the first row, but better if from some prestigious university. No clear idea emerges from these speeches, but it is important to conclude: "In fact, we said just that." Quoting Davies:

The main difficulty remains the nature of the time. Today we know that time is inextricably linked to space, and that spacetime is part of the universe just as matter is part of it. As will be seen in Chapter IX, time also has its laws that govern it: time is part of physics. If time belongs to the physical universe and obeys the laws of physics, it follows that time is included in that universe that God should have created. But does it make sense to say that God is the *cause* of time when ordinary experience teaches us that the cause always precedes the effect?

These statements seem correct (even if there is not full symmetry between space and time, as we have said, in time it is difficult to travel backwards): time, space, matter are part of physics. But no theologian has ever affirmed that God is also part of physics (as the title of the book might suggest...).

The same reasoning in *St. Augustine's City of God* gives the opposite result: God exists outside of time and space, so it makes no sense to say that God decided at some point to create the world:

4.2. But why did the eternal God want at a certain point to create heaven and earth that he had not created before? Those who think in this way, if they understand that the world is eternal without any beginning and that therefore it was not created by God, are very far from the truth and are unreasoned because of their fatal disease of irreligion. Apart from the words of Scripture, the world itself, with its ordained becoming and movement and with the great beauty of all visible things, in a certain sense tacitly affirms that it was created and that it could only be created by a God of inexpressible and invisible greatness and beauty. Others, on the other hand, maintain that the world was created by God, but that it did not have the beginning of time but of its existence. They would say with a barely understandable concept that he was created in eternity. These, it is true, express a theory by which they believe that they are defending God from an act of fatal thoughtlessness. That is, one should not believe that the idea of making the world suddenly occurred to him, which he did not have before, and the decision he had never had was so incisive, since it is quite immutable. [...] Let them believe, therefore, that the world could have been created in time, and that it is not for this reason that God, in creating it, changed the eternal order of his will. [...]

And if they say that human thoughts are nonsensical in which infinite spaces are imagined, since there is no space outside the world, they are told that for the same reason men foolishly think of the past times of God's inactivity, since there is no time before the world. [...] God, in whose eternity there is no becoming, is the creator and orderer of time. [...] So without a doubt the world was not created in time but with time.

7.17.1. *More on the thermal of the Universe*

We began the discussion on the eternity of the world from Aristotle's arguments on the "arrow" of time ("time by itself leads to corruption") and Kant's ("an eternal universe would already be dead"). In modern terms, these observations fall within the laws of thermodynamics: the entropy of the universe increases in continual action.

But at the same time that concepts thermodynamics were defined (by Ludwig Boltzmann), $E=mc^2$ equation was written in Bern by a clerk in patent office. The consequences of this equation are numerous: the stars, which produce electromagnetic radiation from inanimate matter, which living beings then use for their constructions (bio-

logical, architectural, etc.). With the action of flowers, bees, ants, philosophers – the entropy decreases: beautiful, useful, logical artifacts are produced.

Many physicists (and computer scientists) have been busy answering the question of the thermodynamic arrow of time. Gell-Mann, who completed the picture of elementary particles with his quarks, in his book *Jaguar and Quarks* asks⁶² how the information acquired affects entropy, and cites the works of the famous quantum physicist Charles Bennett:

The device can actually use the recorded information to pass heat from a cold object to a hot one [thus reversing the time arrow], *as long as the device has white paper or free tape available*. The entropy of the system composed of hot and cold objects is thus decreased, but the price of consuming the paper or tape. [...] Eventually the device will exhaust the recording space, so that in the long run, when the recordings are deleted to make way for others, the second law of thermodynamics will be restored. (p. 237-8).

Here Gell-Mann touches on an important topic: information. Heisenberg's principle of "indeterminacy" is nothing more than the principle of lack of information: the electron "knows" where to go, it is we who cannot predict where it will go. Einstein's "relativity" does not take away determinism, but limits our access to information far away in space and time. Experiments in recent years⁶³ have shown that with information it is possible to invert the second principle of thermodynamics. But! always "disposing of information", that is, acquiring and processing it. In the material world there will soon be no atoms to store the information if we want to know everything. The Divine mind, on the other hand, is not part of the physical world...

⁶² We note that Gell-Mann's language remains extremely hermetic: "Given an appropriate coarse-grained ratio, we can trace the thermodynamic arrow of time back to the initial simple condition of the universe and to the final condition of indifference implicit in the quantum mechanical formula for the probabilities of coarse-grained histories of the universe." M. GELL-MANN, *The quark and the jaguar*, Bollati Boringhieri, Turin 2000, p. 261.

⁶³ E. LUTZ, S. CILIBERTO, *Information: From Maxwell's demon to Landauer's eraser*, «Physics Today» 68/9 (2015) p. 30.

7.18. Messori: Some reason to believe

Several people have led me to write this book – including Dott. Vittorio Messori, to whom I had asked the question, twenty years ago, why not write a book on science and faith. He replied: "Yes! but how do you do it?" In fact, science has become hermetic, as another Italian, already cited prof. Antonino Zicchichi, points out⁶⁴:

The *ivory towers* of our scientific laboratories are overflowing with fascinating works: extraordinary masterpieces of incredible intellectual power. The achievements of the Sciences, however, have almost always remained the exclusive privilege of a very small circle of specialists. [...] When an intellectual conquest – whether of a strictly scientific nature or of exclusively non-scientific origin – remains in the world of things unknown to most, it, although known to a group of specialists, does not become part of what is called culture.

On the other hand, because of the fear of not being understood, scientific discoveries in disclosures are trivialized, the doubts of scientists carefully hidden, the bridges with previous thought – both physical and philosophical – burned.

It is therefore appropriate, in finishing the reading of the scientific book, to discuss the humanistic culture, which not only complements the scientific one, but makes it less material, aimed more towards the heaven. Faith helps the physicist as a person. But if one insists, faith is not necessary for the mathematical congruence of physics as a science.

Vittorio Messori answers the question of the eternity of the world in *Some Reason to Believe* (p. 272):

The solution to the enigma lies in our being "entangled in time and space". It is in these dimensions, in fact (and in these alone), that the cause-effect chain unfolds. The "First Cause" is outside of it: God is the Eternal and the Infinite par excellence. He is, by definition, "the Fuori-Serie": he is not the first link in the linear series of creatures of which he is the Creator.

On a God-universe (i.e. on pantheism) he continues as follows: "For us, however, God is in the world, to the point of becoming incarnate as man; but at the same time, it is out of the world, it is radically distinct from it. Creation does not coincide with the Creator."

⁶⁴ A. ZICHICHI, *Why I believe in the Him who made the world. Tra Scienza e Fede*, Il Saggiatore, Milan 1999, p. 98. Trans. GK.

Many of the topics covered in this book are the fruits of reflection on books by great Christian authors on faith and science, such as Dominique Lambert, Jean Guittou, Adolphe Gesché, Thierry Magnin and others. The question of the genetic, mental, and cultural uniformity of all human beings, treated in such detail here, was the result of the words of the then Cardinal Ratzinger in his interview with Vittorio Messori⁶⁵:

In an evolutionary hypothesis of the world (one to which a certain "theilardism" corresponds in theology) there is obviously no place for any "original sin". This, at most, is nothing but a symbolic, mythical expression, to indicate the natural shortcomings of a creature like man who, from imperfect origins, goes towards perfection, goes towards his complete realization. To accept this vision, however, means to overturn the structure of Christianity: Christ is transferred from the past to the future; Redemption means simply walking towards the future as a necessary evolution towards the better. Man is nothing but a product not yet completely perfected by time, there has been no 'redemption' because there is no original sin to repair but only a lack that, I repeat, would be natural.

It remains out of our possibilities of reasoning whether the original sin was committed by Adam or by Eve: sin and redemption extend beyond, beyond the physical world.

Let us close with other words from Messori (and the psalmist), on the immensity of the Universe and the smallness of man⁶⁶:

Therefore, the immensity of the Universe is not at odds with God's attention to a dot of this. So he wanted. And so he could and can. The Christian's attitude is not presumption: it is the affirmation of a mysterious reality, the truth of which has been confirmed to us by modern science. The Universe is immense, the more we touch its mystery, the more its size amazes us. But this is precisely what confirms the eighth psalm (also significantly taken up in the *Letter to the Hebrews*): "O Lord our God, how great is your name in all the earth! Above the Heavens rises your magnificence... If I look at your heaven, the work of your fingers, the moon and the stars that you have fixed, what is man that you should remember them, the son of man that you should care for them?" And yet, the psalmist continues, "yet you have made man little less than the angels, you have crowned him with glory and honour, you have given him power over the works of your hands, you have put everything under his feet..."

⁶⁵ V. MESSORI in conversation with Joseph Ratzinger, *Report on Faith*, San Paolo, 1985.

⁶⁶ V. MESSORI with A. TORNIELLI, *Perché credo. A life to render an account of the faith*, Piemme, Casale Monferrato 2008, p. 346, trans. GK.

7.19. Separating the wheat from the chaff

The most difficult task in reading scientific news is to be able to distinguish the important news, which will remain so even in a year, ten, a hundred, from the pseudo-news that make headlines today (and increase the audience rating) but create damage both to the credibility of science and to the collective imagination. A piece of news in this second series is, for example, the terror of the black hole, which can swallow the entire Earth: hypothetically created (but impossible in practice) during experiments on elementary particles at CERN. One of the causes of this kind of ignorance of the "public" is the inability of scientists to say "for the moment I don't know yet".⁶⁷

1° There are different forms of "chaff": sometimes they are simply errors (or rather limitations) of scientists, sometimes they are almost provocations to attract the reader's attention. No one is immune to these aberrations, not even the greatest scientists. Einstein himself, who won the Nobel Prize for the photovoltaic effect (thus also explaining color vision), opposed modern quantum mechanics, telling Niels Bohr: "God does not play dice". And Bohr replied: "It will not be Einstein who tells God what to do."

One of Einstein's objections to the correlation laws of quantum objects, the so-called Rosen-Podolsky-Einstein paradox, turned out to be unfounded, but led to the birth of quantum cryptography. Scientists vainly create alternative versions of quantum mechanics to that of Heisenberg and Schrödinger, looking for some hidden variables that govern phenomena that seem random to us. Decades of experiments to test Einstein's doubt that the quantum states of two photons remain correlated even at great distances should close the last doubts shortly⁶⁸: it will undoubtedly lead to the Nobel Prize⁶⁹.

Another idea of Einstein's, which could bypass the speed of light limit in intergalactic travel, is still false. In 1935, trying to unify the theory of gravity with electromagnetism, Einstein coined the idea that

⁶⁷ Let's take the example of the recent discovery (or rather an experimental confirmation) of the Higgs boson. In Leon Lederman's popular book this boson is called "God's particle", in journalistic interpretations a particle that provides mass to all others, in the answer of a theoretical physicist, if the particle exists, "it exists, because its *Lagrangian* exists" and the commission for physical education of CERN laboratories "is still working on the interpretation".

⁶⁸ Vedi: ALAIN ASPECT, *Viewpoint: Closing the Door on Einstein and Bohr's Quantum Debate*, «Physics», 8 (2015) 123, <https://physics.aps.org/articles/v8/123>.

⁶⁹ This sentence was written in 2019. Allan Aspect won Noble Prize in 2022.

space-time could form folds like a carpet that is not fully extended and that it would be possible to travel instantaneously through these folds like a moth. A name was invented for tunnels of this type: *wormholes*. As the website of the American Physical Society comments, general relativity posed such mathematical and conceptual difficulties that even its creator bowed⁷⁰. Now wormholes turned out to be non-existent⁷¹: a Mexican scientist, Michele Alcubierre, working further on these (hypothetical) folds (and tunnels), came to the conclusion that yes, they are possible, but they require large amounts of energy. In other words, jokingly, if you can reach the next star, you would need the energy equivalent to the mass of Jupiter. Is it worth depriving the sky of a planet as bright and beautiful as Jupiter?

2° But if Einstein proposed experimental tests in all his theories, certain ideas are completely science fiction and, lacking the requisites to be verified, are harmful to the seriousness of science. If accepted, they would be pure *beliefs*. On the contrary, they are distinguished from religious faith by the lack of other meanings, for example ethical. An emblematic case of an idea that cannot be verified (and conceptually dangerous because it deprives man of his individuality) is the concept of parallel universes (a title perhaps taken from Plutarch's book on Caesar and Alexander). Max Tegmark, a well-known cosmologist, hypothesized that there are other universes, either all closed like soap bubbles or parallel to ours, in which we should have twins, who mirror our lives.

Tegmark's universes are not to be excluded from the point of view of physics, but in the sense of Ochkam's razor they cannot exist. And they are a bit like Giordano Bruno's cosmological ideas⁷².

3° The third level of pseudoscience are the amateur "reformers". There are endless works to downgrade the theory of relativity: it is not

⁷⁰ «The paper also illustrates how general relativity posed mathematical and conceptual difficulties that foxed even its creator», *Phys. Rev. Focus* 15, March 25, 2005, p. 11.

⁷¹ «Further theoretical work showed that the Einstein-Rosen 'wormhole' is not, contrary to outward appearances, a stable structure. For an observer trying to pass through, the wormhole opens up and closes too quickly for even a photon to get through. Later work suggested that exotic forms of energy threaded through a wormhole might keep it open but it remains unclear whether such arrangements are physically feasible.» <https://physics.aps.org/story/v15/st11>.

⁷² Giordano Bruno, a Dominican, was condemned not for his cosmological ideas but for the denial of the divinity of Jesus. However, the fact of its execution remains deplorable: the Church is a divine institution, but made up of men.

true that light always travels (in a vacuum) with the same value, there were experimental errors in the measurement made by Albert Michelson and even conceptual errors in the interpretations. Alternative theories are proposed, so full of mathematical formulas that it becomes impossible to follow them. The basic flaw of this work remains the same: in addition to denigrating Einstein's theory, they fail to predict other, new experimental facts that could give conclusive answers. These are long but useless attempts, even fine brains, but which remain useless. A dear mathematician friend, who died prematurely, Giuseppe Vigna Suria, commented on three hundred years of inconclusive work to verify Fermat's equation ($a^3+b^3=c^3$) as follows: "If these efforts had been dedicated to medicine, where would humanity have gone today?"

4° The fourth method of criticizing current science has social and/or ethical reasons. Indiscriminate scientific progress, or even better – often sectoral economic interests – lead to the exploitation (and depletion) of natural resources, environmental pollution, and the growing poverty of a large part of humanity. On these negative aspects almost everyone agrees. But technical and scientific progress has also allowed the cloning of animals, the growth of artificial organs, and denatured biological hybrids⁷³. Also in this case, the ethical perplexity remains clear.

More complex are the judgments on actions that benefit "society" but can be harmful to individuals. At the beginning of the era of mobile phones, there was a lot of discussion about their danger. The scientist should say that the electromagnetic waves in the range used by mobile phones carry the energy too low to cause DNA damage. But we should also add that there is no clinical data for brain exposure for hours of phone calls. Existing standards for workers exposed to microwaves define the hazard at the level of 10 mW (for a whole body). The signals emitted by modern mobile phones are below this limit. And no one should put their own head inside the microwave oven.

In the case of vaccinations – another widely discussed issue – the interests of the producers are, of course, to expand the number of diseases treated as much as possible. Even from a collective point of view, a contagious disease in the school classroom causes serious

⁷³ For example, by modifying genes, eyes can grow on the legs of flies. As long as it's gnats, the news doesn't make an impression, but a dog...

damage to many children, including the importer of the infection. But individually, too many vaccines could be risky: a bit like going by plane harms the environment, harms the airport's neighbors, carries a certain risk of accident, but in total allows huge flows of people and goods in a short time. Vaccines are indispensable⁷⁴.

A bit similar is the case of transplants. The donor's body needs to be in a fairly good state of health. But how to decide, if the body is "dead" and not only in a state of brain death? Plato considered the soul infused into the whole body, not just the brain. Clearly, it would be better to have artificial kidneys (or heart). The hope is to reach soon this level of the technical progress.

5° Really harmful to society, especially to the young, remains the fifth type of pseudo-scientific propaganda: based on theories and phenomena that exist but mixed in such a way as to obtain pure fantasies: the cosmic currents that influence our lives, the television seers, the spirits that speak, etc. Yes, physics does not exclude signals that propagate from the future to the present, it does not exclude telepathy, but everything indicates that the *principle of causality* cannot be overcome: the cause of happiness in our life remains a long and honest job and not a random phone call to the TV wizard. The Christian faith professes the communion of saints, that is, their presence in our earthly life, but it does not take away the responsibility of our personal actions.

7.20. The Lord is subtle

We discussed how even on "simple" issues, such as telephonies and vaccines, everyone brings their own personal idea. Reasoning, in the human mind, is conveyed with emotions. It is not possible to "prove" the existence of God, although it remains licit to try it. Without a doubt, those who believe in God have an extra support in life.

Speaking of Marcus Aurelius and Plato, we showed how believing in the Transcendental helps to build ethics. But there is more: the conviction of the existence of God enriches our view of nature, including physics. Carlo Rovelli, physicist and cosmologist, who for many years tried to unite quantum theory with relativity, writes about quantum mechanics and Heisenberg's uncertainty principle: "It is as if God had

⁷⁴ Again, this sentence was written in 2019, before the pandemia.

not drawn reality with a heavy line, but had limited himself to a slight hatching".⁷⁵ And Albert Einstein said: "Subtle is the Lord".



Fig. 7.6. The coming of Christ, as narrated in the Prologue of the Gospel of St. Mark (and in St. Paul's first letter to the Corinthians) encloses an arc between Creation and Redemption, Here: the Man who came to save man, from original sin, in the representations at the Convent of San Marco in Florence (Fra Angelico, 1442) and at the cathedral of Santa Maria Assunta in Volterra (wooden group, unknown author, 1228). PHOTO: MARIA KARWASZ, 2004.

⁷⁵ C. ROVELLI, *Seven short lessons in physics*, Adelphi, Milan 2014, p. 27.

CHAPTER VIII

Let's read again

Among many different translations, even in Italian, we have looked for a middle way: one text describes God's work as "beautiful", another as "good". In one version "a rushing wind blew over the waters", in another "the Spirit of God hovered over the waters". No doubt, both the original Hebrew and the translations find it difficult to *verbalize* hidden concepts. Let us try to summarize, as the biblical text agrees (or does not agree) with scientific discoveries.

8.1. "A mighty wind"

The first words of *Genesis*¹ speak of "heaven and earth".

¹In the beginning God created the heavens and the earth.

²The earth was empty and desolate, darkness covered the deeps, and a fierce wind blew over all the waters

Here the text seems very confusing. God creates the "earth" at least twice, at the beginning and the second time after the parting of the waters "below the dome". Maybe the word "earth" has different meanings? And "the sky"? In Italian (and Polish) the same word is used for the sky in the meaning of heaven and of the atmospheric and cosmic space above our head. Could "the sky" have yet another meaning?

Without a doubt, as modern physics and cosmology teach, in addition to visible things there is an infinity of invisible "things". Electromagnetic waves – those from television, mobile phones, X-rays – are invisible. The neutrinos, coming from the Sun, which in every second cross our body in quantities in billions per square centimeter, are un-

¹ Unless otherwise specified, we use: *The Bible. Interconfessional translation into current language*. Italian Church, <http://www.lachiesa.it/bibbia/tile/index.htm>. See also the note on the choice of the particular language version on page 15.

detectable. Gravitational waves: only in 2015 was the first, very faint one recorded, which dilated our Galaxy by just one meter (and for 0.12 seconds); but even these probably arrive one a week, without our knowledge; not to mention matter and dark energy, which does not necessarily pervade distant galaxies: it can be among us, in a quantity 25 times more massive than all known matter (i.e. visible + invisible).

Whether or not one believes in the existence of the non-material world is a personal characteristic: it depends on one's own experience and/or sensitivity. The author of this book is more than convinced of the existence of the non-material world, intertwined in a non-separable way with our normal space-time world. Many examples could be given, but they would always be personal. Rather, I invite readers to recall some "coincidence" that changed their lives.

When God created earth and heaven in the first words, we are undoubtedly talking about the *material* world, immersed in space-time, and the extra-material world, of which we can only have some intuition and never a physical measurement.

The description of primordial matter – molasses of the heaviest quarks (*top* and *bottom*) of which the world presumably consisted in the first 10^{-12} seconds (not to be excluded than even more exotic particles) – as "a formless and empty mass" *is no less precise* than the scientific description, but much *easier to understand*, even today.

"The Spirit of God" that appears in the alternative translation could be an important addition: to infinitely disordered, extremely hot, totally unstable matter – the self-organization in "normal" matter, i.e. atoms composed of protons, neutrons, electrons – was no way yet determined.



Fig. 8.1. The unknown author of the mosaics of St. Mark's Cathedral in Venice (thirteenth century) has grasped very well the meaning of verses 1-2 of *Genesis*: infinite waves shake an abyss - neither sea nor land - and the Holy Spirit flies over them. PHOTO: Kino Editions, image reproduced with the kind permission of the Patriarch of Venice.

This self-organization of pre-matter is one of the most intriguing issues of elementary particle physics: no subtle *tuning* is arranged by the laws of physics (i.e., *of matter*). Creation *ex nihilo* is not only a dogma of faith, but also the most reasonable scientific hypothesis (word of an experimental physicist). The omnipotent and omniscient God, that of Newton and Zichichi, is the One who knew how to make the world flourish from the darkness of the abyss. Then, not "the impetuous wind" but the "Spirit that hovered".

¹ In the beginning God created the heaven and the earth.

² And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.²

The extraordinary beauty (and theological insight) of the medieval mosaic from St. Mark's Cathedral in Venice, fig. 8.1, consists not only in the unique representation of the "abysses" but in the presence of the Holy Spirit before the world was shaped.

8.2. "And He separated the Light from the Darkness"

As already mentioned, a little serious and a little joking, the first "fingerprint" of the material Universe is the "background" radiation, today microwave but initially about golden-colored light, which separated from matter after the Big Bang. But the theological meaning of this phrase from the book of *Genesis* is quite different: "the light was good."

Let there be light! And the light appeared.⁴ And God saw that the light was good, and he separated the light from the darkness.

Solving the mystery of the beginning of the Universe is one of the essential joint achievements of twentieth-century physics, chemistry and astrophysics. The date of 13.78 billion years ago places the temporal and spatial break on our world. The appearance of radiation decoupled from matter about 300,000 years later was a crucial event for physical cosmology. The initial universe was very hot, radiation was constantly converting into matter and matter into radiation. As the universe expanded, it cooled, and even the radiation, which was previously very

² *King James Bible Pure Cambridge Edition* (accessed 29/12/2024)
<https://archive.org/details/king-james-bible-pure-cambridge-edition-pdf>

energetic (billions of eV), lost its energy. Radiation was no longer able to convert into matter. On the other hand, the universe was pervaded by radiation, but this was not yet separable from matter.

Steven Weinberg writes:

This condition existed when the temperature was about 4000 K. This temperature marks the transition from an era "dominated by radiation," in which most of the energy of the universe existed in the form of radiation, and the present era, "dominated by matter," in which most of the energy resides in the masses of nuclear particles.

And Weinberg, who does not declare himself a believer, continues:

It is surprising that the transition from a universe dominated by radiation to a universe dominated by matter took place at exactly the same time that the contents of the universe were becoming transparent to radiation, at about 3000 K. No one knows the real reasons for this phenomenon, although interesting hypotheses have been put forward. In fact, we don't even know which transition happened first.³

But in the first minute of the universe it was matter, without radiation, that pervaded it.



Fig. 8.2. Another interpretation of the separation of light from darkness, not according to experimental physics, but according to the canons of Faith: two angels, one white and one black, are images of good and evil. Fresco of the seventeenth century, in the church of the Dormition of the Theotokos, of Asklepion in Rhodes.

SOURCE: Catalogue of the church, courtesy of the Metropolitan of Rhodes, Msgr. Kyrillos (22/05/2019).

³ S. WEINBERG, *op. cit.* p. 89.

The era of pure radiation did not really begin until the end of the first few minutes, after the temperature had fallen below the level of a few billion degrees Kelvin. In *the beginning*, matter was important, but it was a matter of a very *different* kind than what our current universe is composed of.⁴

In a nutshell, even Steven Weinberg, an outstanding theoretical physicist and cosmologist, found it difficult in the twentieth century to imagine (and describe in words) the beginning of the universe. Not speaking about the proverbial "shepherds of Palestine"...

On the other hand, scientists didn't want to believe in a beginning of the universe either. As Weinberg wrote, "it was extremely difficult for physicists to take *seriously any* theory of the origins of the universe."⁵ Today, the "Big Bang" is part of the education of children. But it must be remembered that it was *physics* that brought the arguments for theology. A coexistence with the mutual flourish.

But leaving cosmology aside, a seventeenth-century fresco in a small church lost south of the island of Rhodes, fig. 8.2, re-proposes the separation of light from darkness in another vision: two angels, very similar, one white and another dark, are subject to God: good and evil. And here the much more difficult question than on cosmic radiation, by Leibniz, arises again: how come the good Lord allows evil⁶? The answer given by Vittorio Messori (and Pascal) is: so as not to *force* everyone to believe in the Redemption. To separate the wheat from the chaff; to make the camel "pass" through a narrow gate in the walls of Jerusalem, called "the eye of a needle".

8.3. "Every living creature that moveth"

The outside world, with flowers, butterflies, sunsets, mountain landscapes inspire the sense of beauty: no two visions are ever the same. Whereas the physical world alone, a dozen particles in total, could give rise to monotony and repetition. An evolution? No! It seems that the Creator found pleasure in making the beautiful (and good) universe, creating everything that flickers and that it flies:

⁴ Ibid., p. 92.

⁵ Ibid., p. 147

⁶ G.W. LEIBNIZ, *Essays on theodicy on the goodness of God, the freedom of man and the origin of evil*, Bompiani, 2005.

God said: 'Let the waters bring forth animals that flicker, and on earth and in the skyfly birds.' ²¹ And God created the great monsters of the sea, and all that lives and darts in the waters. And God saw that it was beautiful. ²² And God blessed them, Be ye faithful, and become numerous, and people the waters of the seas. And let birds also reproduce on earth'. (*Gen.*, 1, 20-22)

Different Churches, not only the Catholic one, were till recently quite skeptical about the theory of evolution. Not because the Bible does not admit it: on the contrary, the account of the six days of creation inspires precisely the idea of gradual development. The essential problem was, as St. John Paul II emphasized, the hasty conclusion that a part of scientific opinion drew from evolution: life created itself.

Further, seems that everything can be reduced to material processes: matter has in itself a sense of self-organization, or a strange ability to draw, after billions of years, on the same "evolutionary" solutions⁷. Hence the popularity, even among believers (not to mention philosophers) of Ilya Prigogine's thermodynamic theory; even if he himself asked questions about the philosophical meaning of science and "whether the world created everything by itself".⁸

As we have already said, evolution, a process with material bases, seems to be guided by a "Wisdom". Without a doubt, attributing to matter the capacity for self-creation is like believing that van Gogh's *Starry Sky* can reproduce itself...



Fig. 8.3. The golden dome of the Baptistery of S. Giovanni in Florence (XIIIth century): the author of mosaics combined the creation of the stars, the Solar System, oceans, fish and mammals, up to Adam and Eve. Jesus Christ rules over all creation. PHOTO: MARIA KARWASZ, 2004.

⁷ We recall the example of microbes, which use the "flagellum" to move in puddles and the same flagella that are used to remove mucus from human bronchi (see fig. 5.10).

⁸ In the book *A New Alliance* (1986, with Isabelle Stengers) Prigogine asked questions about the unity of experimental and philosophical sciences, and his last book-interview with him and other famous scientists (astrophysicists, geneticists, botanists, doctors) is entitled *Le Monde s'est-il créé tout seul?*, Albin Michel 2008. <https://www.agoravox.fr/actualites/technologies/article/le-monde-s-est-il-cree-tout-seul-39843> (accessed 26/05/2019).

8.4. "A living Creature"

The third stage of creation, after the physical and biological one, is the birth of Man. The question whether man is the result of an evolution that has taken place in different regions of the Earth or whether he is a "creature", that is, he suddenly appeared from a *divine breath*, is by no means secondary. Genetics and anthropology do not exclude the instantaneous and localized creation of the human "race". Two statistical distributions of the genome that we have shown in Fig. 6.12 overlap: it remains possible that the particular population studied had the same pair of parents. And, possibly, not only them, as we discussed in chapter VI. But apologetics still shows distrust.

Then God, the Lord, took some earth from the ground and, with it, formed man. He blew a breath of life into his nostrils and the man became a living creature. (*Gen. 2, 7*)

A subtle play on words distinguishes a "lived" creature from a "living" creature. An invisible difference distinguishes an animal's soul from a "breath of life" that God "breathed into the nostrils" of the first man. As we discussed in an article in the Spanish ecclesiastical magazine⁹, the only difference to be proposed, unfortunately not verifiable by the means of physics, is that of the *immortality* of the human soul. But this immortal soul does not only mean "living forever," as Joseph Ratzinger explains:

In fact, to have a "spiritual soul" means precisely to be wanted in a special way, to be known and loved by God in a special way; to have a spiritual soul means to be a creature called by God to an eternal dialogue with him, a creature therefore capable in turn of knowing God and responding to him.¹⁰

So, "a breath of life" sent into the nostrils of Adam means an immortal soul: given to the first *Man* as such, to every individual man under his mother's heart. Man, as a *substantial* unity of the body and the soul - we refer the reader to Plato and Aristotle. Accepting the creation of man solves yet another modern dilemma: the identity of man and woman and our relationship with nature.

⁹ G. KARWASZ, *Aristotle's three souls in modern science: Re-reading "De Anima"*, «Cau-riensia» 13 (2018) pp. 429-458.

¹⁰ J. RATZINGER, *Introduction to Christianity*, Queriniana, Brescia 2010, p. 345.

God created man like himself, he created him in the image of God, male and female he created them. He blessed them with these words: 'Be fruitful, become numerous, populate the earth. Rule over it and have dominion over the fish of the sea, and the birds of the air, and over all the animals that move on the earth.' (*Gen.*, 2:27-28)

The likeness to God assigns to every single man "inviolable and inalienable rights"¹¹, which need no institutional confirmation. Maria Montessori said: "Seek God first of all, and the rest will come of itself with abundant fruit".¹² With the same verses of *Genesis*, man is obliged to respect creation as such: it is a theme dear to Pope Francis.

The question that came to several thinkers, including Albert Einstein, is: how did God create man in His image? Were there no other possibilities? Einstein, from the observation of the anthropomorphic God, even arrives at dangerous proposals on a universal, cosmic religion, and on morality, which may not come from God but be a fruit of man's good intentions¹³. Obviously, the totalitarianisms of the twentieth century have tested, to tens of millions of victims, where a non-religion-based morality leads. We subscribe with conviction to the words of Vittorio Messori: "first Faith, then ethics".



Fig. 8.4. We use once again the image from St. Mark's Cathedral in Venice, from the thirteenth century, when, in the absence of genetic knowledge and official theological canons, artists had to use their individual, intrinsic religious intuition: the Adam on the dome of *Genesis* is an African. A cultural openness typical of the Venetians or a stroke of genius? SOURCE: Kina Edizioni, courtesy of the Patriarch of Venice.

¹¹ Words of the preamble of the European Constitution, see: https://europa.eu/european-union/sites/europaeu/files/docs/body/treaty_establishing_a_constitution_for_europe_it.pdf

¹² M. MONTESSORI, *Educare alla libertà*, Oscar Mondadori, Milan 2008, p. 50.

¹³ "Man's ethical conduct must be effectively based on compassion, education and social bonds, without recourse to any religious principle." A. Einstein, *How I See the World*, op. cit., p. 27.

8.5. The tree of knowledge

God created man not only with a "rational soul" as Aristotle already noted, but he also provided us with ethics. And unlike "civil" codes such as Hammurabi's, the ethics of the Bible teach not only fear but first of all love. The justification is always the same: "I am the Lord your God":

¹⁴ Thou shalt not curse the deaf, nor put a stumbling block before the blind, but shalt fear thy God: I am the LORD.

¹⁵ Ye shall do no unrighteousness in judgment: thou shalt not respect the person of the poor, nor honour the person of the mighty: but in righteousness shalt thou judge thy neighbour.

¹⁷ Thou shalt not hate thy brother in thine heart: thou shalt in any wise rebuke thy neighbour, and not suffer sin upon him.

¹⁸ Thou shalt not avenge, nor bear any grudge against the children of thy people, but thou shalt love thy neighbour as thyself: I am the LORD.

(Lev, 19, 14-18, King's James Bible)

Original sin was a transgression: disobedience to God. But a particular transgression: the desire to be able to distinguish good from evil on one's own; in other words, to build ethics to the measure of man. Not only did Marcus Aurelius show himself full of doubts about self-formulated ethics; even in the twentieth century it is not possible, with the sole use of philosophical thought, to define the individual and common good¹⁴.

⁹ And out of the ground made the LORD God to grow every tree that is pleasant to the sight, and good for food; the tree of life also in the midst of the garden, and the tree of knowledge of good and evil.

¹⁶⁻¹⁷ And the LORD God commanded the man, saying, of every tree of the garden thou mayest freely eat: But of the tree of the knowledge of good and evil, thou shalt not eat of it: for in the day that thou eatest thereof thou shalt surely die. (*Gen. 2*, King's James Pure Cambridge Edition)

The man of the twenty-first century tries to reap the fruits of both trees: to maintain infinite beauty and vigor over time and immeasurable wisdom. We are all convinced that it is not possible to have all material goods. But no one, except for a few great scientists, is aware that even wanting to know everything is a sin of pride.

¹⁴ An example of vain attempts to define the ethical good is the work of George Edward Moore (1873-1958): it should be the action that brings happiness, possibly to everyone. But how do you know to whom and when? See G.E. MOORE, *Principia ethica*, Bompiani, Milan 1964.

Thus we have arrived at the "core" of the Science-and-Faith discourse: we do not need to know masses of quarks in order to live with a healthy inner moral compass. It is good to know that there are scientists who study quarks masses, it is nice to meet them, but the Faith is superior to cold science. Important is to make Faith felt and reflected upon. A superficial faith is just a custom or a superstition.

The punishment for Adam and Eve's disobedience was tremendous: fatigue and death. And because they could not access the tree of life, they were cast out of Eden. But Almighty God must also be infinitely merciful: the world would already have collapsed in on itself under the weight of evil. Thus, God "delegated" his own Son to redeem sins not only of Adam and Eve but of all men, until the end of times. And the Son became man, to all intents and purposes of the material world¹⁵, equal to us in thoughts and feelings, except sin.

The answers to why God shaped us in His image can be many. Perhaps the most important is to be able to participate in our human aspirations, desires, attempts, failures. An exceptional Polish s-f writer, Stanislaw Lem, of great human culture, but who became an atheist after his painful experiences under the Nazi occupation, addressed this question in one of his stories. His answer was: to be able to understand us, that is, to share our human stories. God is among us: Emmanuel!



Fig. 8.5. (a) God's gesture is very clear: a prohibition. Palatine Chapel, Palermo, XIIIth century. (b) St. Dorothy's Altar, Gdańsk Cathedral.



¹⁵ Until the Council of Florence (1439) there was the tradition of presenting, in the Annunciation, the breath of the Holy Spirit who also sends the small human body. Such an image is found in the Cathedral of Gdansk (altar of St. Dorothy, England, 1435). This interpretation was forbidden: a body from heaven could not have suffered on the Cross (thanks to Dr. Maria Teresa Lezzi Gorga for these explanations).

8.6. Emmanuel, that is, God among us

Having to defend the Faith, the first question to ask is in what way Christianity remains particular compared to other religions. In all cults there have been martyrs, in all religions certain individuals such as pharaohs have enjoyed divine worship. Christ was declared king, but only by Pilate, in the description of the condemnation. The Angel called him Jesus:

But while he thought on these things, behold, the angel of the Lord appeared unto him in a dream, saying, Joseph, thou son of David, fear not to take unto thee Mary thy wife: for that which is conceived in her is of the Holy Ghost. And she shall bring forth a son, and thou shalt call his name JESUS: for he shall save his people from their sins.

Now all this was done, that it might be fulfilled which was spoken of the Lord by the prophet, saying, behold, a virgin shall be with child, and shall bring forth a son, and they shall call his name Emmanuel, which being interpreted is, God with us. (*Mt*, 1, 20-23, King's James Bible)

Christian dogmatics seems to make little sense: a Son of God, incarnated by the work of the Holy Spirit, grown in the womb of the Immaculate Virgin Mary, died crucified and then resurrected. It is a pure reasoning that is difficult to explain. Faith remains, the second "wing of the human spirit", to quote St. John Paul II.

His successor Joseph Ratzinger, one of the greatest theologians of all time, wrote in 1968: "The person of Jesus *is* his doctrine, and his doctrine *is* himself. Therefore, the Christian faith, that is, faith in Jesus as the Christ, is truly 'personal faith'".¹⁶

This is precisely the characteristic of the Christian faith: to be personal. Face to face, in the semi-darkness of the confessional, with the priest as a mediator, but only thanks to an explicit assignment given to him by Jesus. For the rest – no collective responsibility, no holy war, no emperor behind a patriarch. No certainty or "shortcut" – not even on the side of science. Christianity is a religion of free choice.

Continuing with the explanations of Pope Benedict XVI and his 1968 book, one can compare the birth of Jesus to further creation:

¹⁶ J. RATZINGER, *Introduction to Christianity*, *op. cit.*, p. 197. First edition (in German) 1968. [provisional translation from Italian, GK]

Jesus' conception is a new creation, not a procreation by God. God does not thus become the biological father of Jesus, and neither the New Testament nor the theology of the Church have in essence ever seen in this account, and in the event narrated therein, the foundation for the true divinity of Jesus, for his 'divine sonship'. This, in fact, does not mean in any way that Jesus is half God and half man, but for faith the fact that Jesus is *entirely* God and *entirely* man has always been fundamental. His being God does not entail a subtraction from his being man [...] In fact, divine sonship, of which faith speaks, is not a biological fact, but an ontological one; it is not a process that took place in time, but in the eternity of God: God is always Father, Son and Spirit; the conception of Jesus means that a new God-Son is born, but that God, as the Son in the man Jesus, attracts to himself the creature man who *is* himself man.

Difficult words, right? Theology far surpasses physics. Faith, for a believer, constitutes an anchor, a safe haven. Science helps to reason but only acts as a support. And the Catholic Church popes of recent times, starting with John XXIII, have insisted on a third "support": love. They were preceded by young saints (St. Therese of the Child Jesus, St. Faustyna Kowalska) who wanted to be martyrs for the love of Christ. And the first to love Him (and meditate) was Holy Mary.



Fig. 8.6. Maternal love is the archetype of all loves. But only God's love for his creation is infinite. It is not the beauty of the painting that strikes us, but the always fresh flowers underneath, the sign of love of the pilgrims towards Our Lady. ANDREA DELLA ROBBIA (ca. 1500), Basilica Maggiore della Verna, photo MARIA KARWASZ, 2005.

Conclusions

9.1. On the constant progress of frontiers

Throughout the book we have seen how different terminologies, arguments, reasoning changed their meaning over the millennia of the history of culture. For the pre-Socratic Greeks the most urgent was the concept of matter – so they invoked "air", "water" etc., that is, "the states" of matter as they are called in English or "the states of condensation" literally translating from Polish.

For a brief historical period – a few decades between the nineteenth and twentieth centuries – it seemed that the question of matter had been solved: these are atoms, differently arranged (i.e. at different distances), that form the solid, liquid or gaseous state. Then, all atoms are made of electrons, protons, and neutrons. The number of electrons (equal to the number of protons) determines all chemical properties of an element. The concept of "matter" passed definitively from the domain of philosophy to that of physics and chemistry.

With Einstein's $E = mc^2$ again this clarity has disappeared: in theory, any form of energy can be transmuted to any form, even a very strange, of matter. Obviously, respecting some *principles* of physics. In Aristotle's terms, the reality of matter, visible, palpable, becomes a *potentiality* of matter: two beams of ultrafast electrons would travel in infinity, but by making them collide *we can* produce a new matter. Thus, the physical clarity of "matter" again acquired *metaphysical* connotations: we are not able to explain with the rules of physics (i.e. mathematics) the *exact* proportions that these and not other elementary particles are created in the collision. We "believe" in these rules, without knowing how to explain them.

The concept of matter is just one of many examples of terms, of which the conceptual domain shifts between physics and metaphysics – up and down, left and right, all the time. *Space* and *time* are a similar

case. Aristotle included them in his *Physics*, and they created quite a few conceptual difficulties. The outcome of various considerations of time was only the definition of the moment "now" (as on a point on the Cartesian axis) and of the past (as on the semi-axis to the left) and of the future. In the question of space, Aristotle was a little more conclusive: space is the distance between one edge of a body and another. In other words: space is a part of matter, and without matter it would hardly exist.

With Galileo's brilliant considerations, space acquired abstract-mathematical connotations: the reference system is defined *a priori* in every physical exercise carried out. Physical objects are "inserted" into this system only later. Continuing this reasoning (and seeing the difficulties with which Newton had to deal with gravitational action at a distance without a clear physical means), Kant attributed to space and time a "transcendental" existence – both have become categories of pure reason. Until the time of Einstein, who with the general relativity brought both space and time back to the physical matter.

And in our (i.e., the author's) "theological" interpretation, both the space and even more the time are the ways in which the good Lord has anchored us: the human soul, made in His likeness, but in a body (in the vast majority of cases) mortal - subject to physics and biology.

The continuous interweaving in this book between philosophy, science and faith is the consequence of a partial superimposition of certain concepts and imaginations. The frontiers between the "three highest theoretical sciences" of Aristotle (physics, mathematics, and metaphysics) are constantly advancing – not in one direction, but permanently revolving, like the spinning Earth illuminated by Sun continuously in its diverse regions.

The idea of moving borders is not new. Aquinas repeated the Aristotle's categories: mathematics, which deals with objects in space (but not necessarily in matter), physics, which deals with objects that *exist* in space and matter, and theology, which deals with objects which *cannot* exist in space and matter. The latter "objects", for example, may be angels. But as we discussed in Chapter VI, the two worlds – material and immaterial are not much separated.

In the preface to the "Commentaries on Boethius" by St. Thomas, Pasquale Porro writes:¹

¹ THOMAS AQUINAS, *Comments on Boethius*, Rusconi, Milan 1997, p. 28-29.

In any case, Thomas does not interpret Boethian grid [of three sciences] in a rigid way: each way of proceeding, in other words, must not be considered exclusive to the science to which it is assigned, but as particularly appropriate or convenient to it. For example, physics is not the only science that makes use of the rational way of proceeding, but it is the one that best responds to the internal dynamics of our reason: it is in fact proper to reason to move from sensible realities to pass to intelligible ones and proceed discursively (and not with a simple intuitive act) from one thing to another, and both these characteristics are found principally in the procedures of natural science.

As for mathematics, it represents for Thomas – as already partly anticipated – the science capable of ensuring absolutely greater certainty: more than natural science, because it abstracts from matter and movement, which always involve a certain component of instability and contingency; but even more so than divine science, in so far as it offers the advantage, compared to the latter, of considering realities less distant from the senses and from the imagination.

Returning to Cardinal Joseph Ratzinger's admonition: there is no "retreat" from the dogmas of the faith. Simply, there is a constant *progression* of the frontiers between physics, metaphysics and theology: the three theoretical sciences, defined as such by Aristotle and St. Thomas. And progressing (on a round sphere) does not imply any direction.

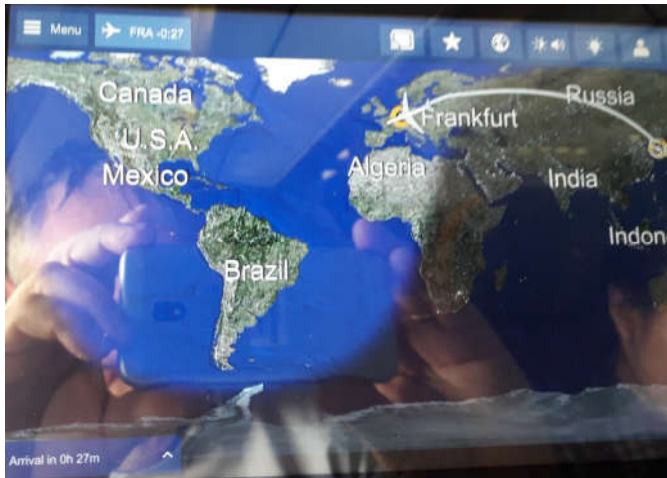


Fig. 9.1. Flying from Seoul to Frankfurt, it seems that it is the areas of shadow (night) and light (day) that are constantly moving on the surface of the Earth. Instead, since the time of Copernicus we know that it is precisely the Earth that rotates. In a similar way, the parts of human knowledge become, alternately, the domain of science, philosophy or theology – in a continuous interchange. PHOTO: GK.

9.2. Why didn't God do everything in a click?

At the first chapters of this book we discussed how a chain of events in the history of our Universe: (chaotic) matter → hydrogen & helium → galaxies & stars → planets & moons → seas & dry, is not trivial. A "naïve" project of the "beginning" would start with the Sun, the Earth and the trees. In such a view, the biological evolution would not be necessary. But knowing that the "earth" environment started from volcanic, acidic and anaerobic conditions, biological evolution was a indispensable mechanism.

Then, the considerations on the first moments of life, initially very simple, anaerobic, with DNA codons probably only 2 letters (and fewer amino acids used), without specialized organs (only the function of oxygen production, for a billion of years, or so): there again, one could think about a shortcut - first dinosaurs and then immediately man? But the oxygen atmosphere born in a chemical way would violate laws of chemistry: oxygen must bind to iron in rust like on Mars.

And God outside of space and time (that are *attributes* of the matter) could immediately create life in its "ready" form? But at this point He would bypass the space and time that He created. Do we need space and time? Yes! To see the beauties of the world. Look below.



Fig. 9.2. Man adds his opera to the beauties of the world created by God: ancient Greeks built theaters in most picturesque places of the Mediterranean such as Taormina, with the emerald sea and the plume from Etna volcano in the background. FOTO: MARIA KARWASZ, 2003.

Then there is an anthropic fact. God created (if we believe) man in his image and likeness (*Genesis* repeats this three times, if not four).² Our mind can travel in an instant to the most distant galaxies, where, however, we cannot send a space probe or even a message: it was Einstein (or God?) who prevented us from doing so. In other words, space and time are not categories of pure reason, as Kant believed, but are very, very real (i.e. physical) anchors that stare at us. Otherwise we would not be "on His image", but "like Him".

9.3. In the beginning there was Logos

We have shown how the whole world (material, because only this is subject to Galilean science) is sensible: very complicated, difficult to understand (like the terms of the general theory of relativity), indeed in some ways impossible even to guess (like quantum mechanics), but undoubtedly logical. Numerous books use the expression "Mind of the Universe" and also our fellow, mathematicians, according to whom God is undoubtedly a mathematician.

Understanding biology means make order in the infinite reactions allowed by the organic chemistry. Also humanities require a comparison, a classification of numerous texts, in different languages, by atheist and believing thinkers, in different political systems and historical periods. We need *order*, that is, *logos* (different from chaos).

Note that we do not use the word "Word", as "Logos" is translated (i.e. with a capital letter): "In the beginning was the Word, and the Word was with God, and the Word was God" (*Jn* 1:1).

Our reasoning on the dogmas of the Faith and comparing the words of the Bible with modern sciences, in a kind of mental "game"- we would call it *scherzo*, using a musical term. But after joking, we must come back seriously to the Word and meditate it again.

² He was in the beginning with God. ³All things came to be through him, and without him nothing came to be. What came to be ⁴ through him was life, and this life was the light of the human race; ⁵ the light shines in the darkness, and the darkness has not overcome it. (*Jn* 1: 2-5, Vatican version)

² "Then God said, 'Let us make man in our image, after our likeness: let him have dominion over the fish of the sea, the birds of the air, and the cattle, and over all the wild animals and all the creatures that crawl on the ground.' God created man in his image; in divine image he created him; male and female he created them." (*Gen.* 1: 26-27, vatican.va).

This time the darkness is not physical, but moral, as in the fresco in the church of Asklepius, on Rhodos Island, see fig. 8.2. The *Bible*, as the great Galileo said, is not a book that explains how heaven is made, but how one arrives to Heavens.

9.4. Five "proofs" of God's existence

St. Thomas, arguably one of the greatest Christian thinker, philosopher, and theologian, defined five "proofs" of God's existence. This evidence was partly based on arguments that are now in physics. Their description is concise and forms the basis of the whole "Theological Summa".

Today – after seven centuries of a vertical growth of human culture: architecture, art, physics, anthropology, etc. – we (GK) can define other proofs.

1) There is a beautiful and immense world.

The world exists, and we know that it is physically extremely complicated: with universal constants "adjusted" to infinity and laws that we are largely unable to understand. A world made like a mechanical clock would be much simpler.

2) There is Man, very complex.

There is Man, who differs in all aspects (except the biology of his body) from all beasts, and who culturally is very complicated. Man, in order to live, would not need all this philosophical complexity.

3) There are believing scientists.

There are scientists, people who meditate, invent, write for most of their free time. Most of these thinkers, after having contributed in an incredible way to scientific progress (Descartes' graphs, Newton's gravity, Leibniz's mathematics), go out of their way to discuss the existence of God. By mistake? Or by conviction?

4) There is culture, i.e. Christian one, for centuries.

Since the medieval times, despite the lack of technical means and the famine, societies have "indulged" in building cathedrals, one more impossible than the other, spending fortunes and millions of years of work. The most gifted artists, in all times, have dedicated their most precious talents to proclaiming the glory of God. Why?

5) There are saints and miracles.

Since the dawn of Christianity, huge crowds of young people, adults, and the elderly have dedicated the gift of their (biological) lives to martyrdom. There are thousands of testimonies of miracles. The lines of the faithful are endless. All for a collective madness? Or for a real transcendental Being? Do we call Him God?

For us it is not the evidence, but only the clues – following Vittorio Messori (and Blaise Pascal) – sufficient to convince those who want, and not oppress those who do not want to.

9.5. Do we already know everything?

No, we don't know. All great scientists admitted this: any essential discovery opens up a sea of the unknown problems ahead. Kepler had discovered the mathematical laws of revolution of the planets but sought almost magical explanations. Newton explained Kepler's laws, but introduced an action between bodies at a distance, all inexplicable, up to Einstein's equation of general relativity. And we know less than 1% of the cosmological consequences of the latter. For the moment...

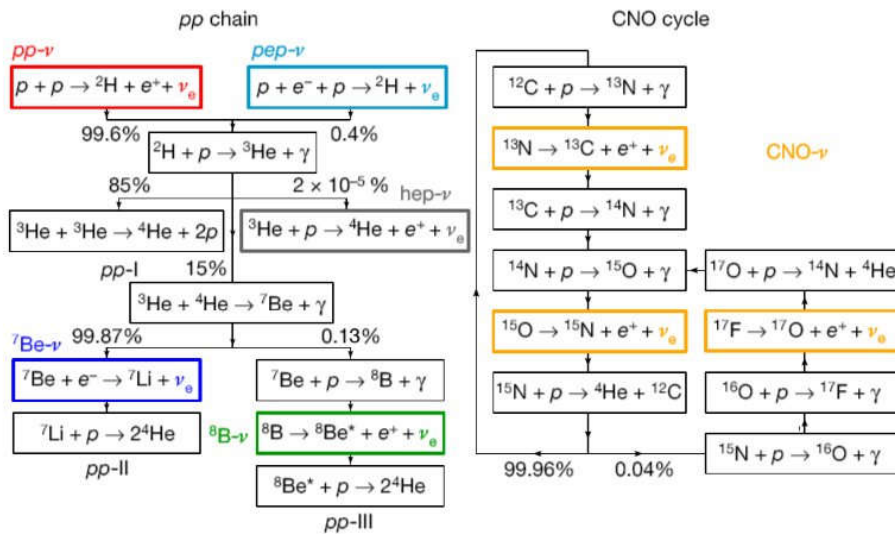


Fig. 9.4. The graph of two chains of thermonuclear synthesis in the Sun. The two reaction blocks are connected by an unlikely passage, i.e. capturing of the α particle ${}^4\text{He}$ by beryllium metastable ${}^8\text{Be}^*$ nucleus (green box). Without this reactions, all stars would die at the stage of helium: no carbon, no life. Experiment Gran Sasso (Borexino collaboration) done in 2012-2016. FONTE: «Nature», 25.10. 2018

The recent (October 2018) results of long measurements of neutrinos from the Sun, made in the Gran Sasso Laboratory in Italy, have made it possible to estimate the individual reactions in the chains of thermo-nuclear synthesis. The graph of the binding energy of nuclides (Fig. 3.15c) shows that the helium nucleus is particularly stable. But to what extent?

The Gran Sasso results confirmed that the two chains of processes – the synthesis that starts from hydrogen (and leads to beryllium, and then back to helium) and the one that starts from carbon to oxygen, form two distinct islands, see fig. 9.4. In other words, the passage between the two chains is so narrow (i.e. unlikely) that the signal has not been seen in the long measurements of four years.

What's more: the passage between two islands is almost a miracle of physics. It is based on an extremely short-lived state of the excited beryllium nucleus. Without it, there could be no carbon neither oxygen. And then, all the chains could fall back to helium, as shown in in fig. 9.4. An eternal world that consumes energy but produces nothing. And the Sun is a "smart" star, which by exploding got rid of heavy ashes such as sulphur and iron, which in turn are useful for inhabitants of Earth...

9.6. St. John Paul II: The Two Wings

All the Catholic popes of the twentieth century have been involved in the discussion (clash?) between Faith and science. We began with Cardinal Ratzinger's speech. But even Pius XII, when he learned about Lemaître's theory, expressed himself with details on the ways in which the age of the Universe can be assessed³:

It is undeniable that a mind enlightened and enriched by modern scientific knowledge, which calmly evaluates this problem, is led to break the circle of a completely independent and autochthonous matter, either because it is un-created, or because it was created by itself, and to go back to a creative Spirit. With the same clear and critical gaze with which he examines and judges the facts, he glimpses and recognizes in them the work of creative omnipotence, whose virtue, acted on by the powerful "fiat" pronounced billions of years

³ *Address of His Holiness Pius XII of 22 November 1951 for the Plenary Session and the Study Week on the Problem of Microsisms*, in: *Discorsi addressed by the Supreme Pontiffs Pius XI, Pius XII, John XXIII, Paul VI, John Paul II to the Pontifical Academy of Sciences from 1936 to 1986*, Pontifica Academia Scientiarum, Vatican City, 1986, p. 80.

ago by the Creator Spirit, unfolded in the universe, calling into existence with a gesture of generous love the matter exuberant with energy. It really seems that today's science, suddenly going back millions of centuries, has managed to bring witness of that primordial 'Fiat lux', when a sea of light and radiation burst out of nowhere with matter while the particles of chemical elements split and reunited in millions of galaxies.

It is not the immutability of the Universe that is the sign of God's greatness, but precisely the dynamism of the world – physical, atomic, chemical, stellar. This mutability also includes the biological world, which we know less precisely than the physical world: not because of the lack of capacity, but because the biological world (and also the chemical world) is by the nature of processes much less predictable than physics, at least the classical one. If we were able to define principles in physics, similar simple statements are not possible (at least now) in biology. Thus, the theory of biological evolution still remains a very fragmented science. It cannot be excluded that it is governed by laws still superior to those of physics, that is, of meta-physics, including the teleological cause.

I use again the explanations⁴ of St. John Paul II:

In his Encyclical *Humani Generis*, my predecessor Pius XII had already affirmed that there was no opposition between evolution and the doctrine of the Faith on man and his vocation, provided that certain fixed points were not lost (cf. Pius XII, *Humani Generis*, 1950: AAS 42 [1950] 575-576). For my part, in receiving the participants in the Plenary Assembly of your Academy on 31 October 1992, I had the opportunity, with regard to Galileo, to draw attention to the need for a rigorous hermeneutic for the correct interpretation of the inspired Word. It is necessary to define well the proper meaning of Scripture, discarding the induced interpretations that make it say what it does not intend to say. In order to clearly delimit the field of their object of study, the exegete and the theologian must keep themselves informed about the results to which the natural sciences lead.

The amount of scientific information with which we are targeted every day is impressive. This information, presented in a fragmented way, seems to be self-consistent, that is, it does not need explanation outside the material world. Scientists themselves hide doubts and open problems from them. For this reason, detailed discourses are needed,

⁴ https://w2.vatican.va/content/john-paul-ii/it/messages/pont_messages/1996/documents/hf_jp-ii_mes_19961022_evoluzione.pdf.

but inserted in the broader philosophical panorama. What are extremely difficult to do...

Dialogue between the natural and human sciences, including theology (sometimes called a "divine" science), remains essential. This exchange of wisdom and opinions must be bidirectional: physics must continually reconsider own philosophical foundations (as Einstein did formulating theories of space-time) and even "the theologian" must keep himself constantly informed about scientific developments, so as not to remain ignorant in the discussion with "the mathematician" (as St. Augustine said) and to "not render the Faith ridiculous" because of our own ignorance.

I conclude the whole discourse on scientific reasons for believing in God with the words of St. John Paul II from the Encyclical "Fides et Ratio":

Faith and reason are like the two wings on which the human spirit rises towards the contemplation of truth. It is God who has placed in the heart of man the desire to know the truth and, ultimately, to know him so that, by knowing and loving him, he can also arrive at the full truth about himself⁵.

The search for truth, even when it concerns a limited reality of the world or of man, never ends; it always refers to something that is above the immediate object of studies, to the questions that open access to the Mystery.⁶

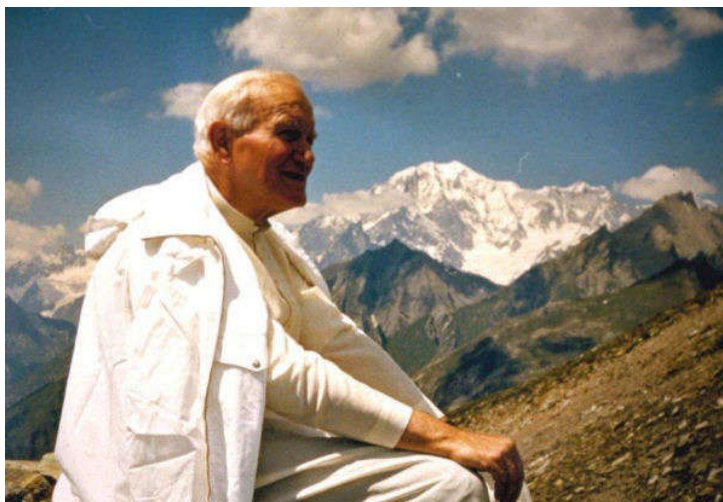


Fig. 9.5. S. Giovanni Paolo II in Val d'Aosta. Courtesy: RAI.

⁵ JOHN PAUL II, *Fides et ratio*. L'Osservatore Romano, Vatican 1998, p.3.

⁶ *Ibid.*, p. 153.

9.7. A summary

The summary of this whole story is short:

1) The Universe, as St. Augustine wrote, is the largest material structure we can know. Copernicus added that we probably cannot know the limits of the universe and Einstein demonstrated this with the theory of relativity.

2) God, according to St. Augustine, is the greatest immaterial ("heavenly") being that exists. This statement must be made clear in Newton's words: God is omnipotent and omniscient.

3) Time and space, according to St. Augustine, were created by God with the world. The Big Bang theory (more than the theory, given all the experimental data), intuited by Lemaître (a Catholic priest), proves that space and time were born with matter. Einstein's general theory of relativity confirms Aristotle's (vs. Kant) intuitions that space and time are part of matter.

4) The theory of relativity sets limits to our knowledge of the infinitely great. Heisenberg's principle (and all quantum mechanics, starting from Schrödinger's equation) prevents us from knowing the infinitely small. The theory of relativity prevents us from knowing the infinitely great.

5) It seems that we can know all the dimensions "in between" the infinitely large and the infinitely small, not only of our stature. And our skull cap manages to enclose the whole Universe, in a thought that is always different, individual and not comparable to anything else.

6) This cap, and perhaps the whole body, as St. Thomas believes, is impregnated with the human soul, which according to Plato is immortal. This is also confirmed by Aristotle, according to whom the intelligent (and immortal) soul is a prerequisite only of human beings, of *Homo sapiens sapiens*, as it is called today by biologists.

7) Modern genetics, with anthropology and the archaeology of culture confirm that *Homo sapiens sapiens* may have begun in a well-defined place and at a precise moment of time, around 120 thousand years ago, somewhere in the African garden.

8) Quantum mechanics, with the special theory of relativity, shows us that the principle of causality, essential for Ockham (not for Hume), is an iron relationship, absolutely intransigent, probably much

more than all the other "principles" of physics. This is a moral constraint for human beings who can influence the world.

9) However, a problem arises: if God exists outside space and time, he also knows the future. Indeed, for Him the future has already happened. How can we change the future? Here St. Thomas replies that God, with our free will, allows us to change the future, in particular with prayer.

10) The principle of causality has consequences not only for physics, but first of all for ethics: any of our actions will have a result. On the other hand, even the good God, in creating the world, did not look at the fact that it was perfect mathematically, but that it was good.

11) So why does evil exist, as Leibniz asked? He replied that God created the world that is not perfect, but is the best of all possible worlds. Yes? A perfect world would not need our good deeds. As Descartes wrote, man can study all books, but this would be a waste of time if he did not also do good deeds in his life.

Finally, the undersigned, professor of Experimental Physics⁷, also graduated in Economics, specialist in atomic physics, anti-matter, solid state physics, dissemination and didactics of physics, believes not only in the Creation of the world, in original sin, in the Redemption of man, but also in the permanent action of the Holy Spirit, in the power of prayer to reverse the fate of the world, in communion with the saints and in the tasks (talents) that the good God has assigned to all his creatures, *first and foremost* to Man.

⁷ In addition to numerous scientific publications (most of them in English), we recommend reading two texts in Italian: KARWASZ, G., *The constant progress of the frontier between theology and science: "Physics"*, "Scientia et Fides", 3, 1 (2015) 61; KARWASZ, G., *The Constant Progress of the Frontier between Theology and Science: "Metaphysics"*, Scientia et Fides, 4, 1 (2016) 151.

CHAPTER IX

Ten questions

As in a manual, we must provide the answers to the most important questions. Here they are!

1) Was there really the Big Bang at the beginning of the world?

Yes, we can explain the beginning of the world with the Big Bang, a cosmic explosion. But knowing that energy and matter cannot be created out of nothing, we cannot explain where all the immense energy and matter in the existing Universe came from.

2) Has there really been evolution?

Yes, there was biological evolution, which within 4.5 billion years of the appearance of life on Earth (or "on the sixth day") led to the formation of *Homo sapiens*. On the other hand, evolution is nothing more than the succession of the laws of nature, which, as Galileo said, "is the most faithful executor of God's orders".

3) Did Adam and Eve really exist?

Yes, modern genetics traces the whole of humanity living on Earth today to a single father and mother, dating back to about 120 thousand years ago, in Africa. The genetic differences between apes and humans seem minimal, but are absolutely decisive for all human characteristics.

4) Was there really original sin?

God expelled Adam and Eve from Paradise when they wanted to acquire the knowledge of good and evil on their own. It is a great sin (*peccatum*) the desire to establish ethical judgments on ourselves, and even worse is to try to impose them on others.

5) Does life beyond Earth exist?

To the state of our knowledge (and according to Professor George Coyne of the Vatican Astronomical Observatory), there is no theological treatise that prohibits it. To this day, of the thousands of planets we have discovered, none resembles Earth.

6) Was there really the Resurrection?

Yes, with all the possible clues that both the laconic (almost absurd) story of St. John "and saw and believed" (20:9), and the image on the Holy Shroud provides, the Resurrection of Christ, first crucified and then dead, really happened. But again, being the cardinal point of the Christian Faith, the Resurrection cannot be scientifically proved.

7) Do we all have to die?

No, if Christ arrives for the Last Judgment during our lifetime, we will be judged "alive." Our Lady was taken into Heaven in flesh and blood, while she got asleep.

8) Can we know God by reason?

No, all philosophers, even those held in high esteem among non-believers, such as Kant, have admitted that without *divine grace* it is not possible to know God. To seek God only with reason is to commit a sin of superbness.

9) What is the most significant trait of the human soul?

The most significant trait is not emotions (because some of these can also be attributed to animals), nor intelligence (for the same reason), but the immortality of the soul. Do we have any evidence? Objective, no, otherwise there would be no need for Pascal's bet. And we, individuals? Everyone should consider his/ her own personal experience.

10) Why does God permit evil?

As a philosopher and physicist, Leibniz, wrote, the sin or the moral evil exists to prevent a worse evil or to induce good. "That is why there is a moral sin or evil, whatever happens so often that it can serve as a means of obtaining one good or preventing another evil."

Ringraziamenti

Il libro è nato dalle domande che ci si faceva durante le piacevoli sedute sul divano verde con il carissimo amico avvocato Mario Fedrizzi, con la bellissima vista sui monti trentini. Spero, dopo anni, di poter fornire parziali risposte da parte mia, cioè dello scienziato. Grazie Mario! per queste domande.

Innumerevoli sono i discorsi e lezioni che ho avuto la grazia di prendere, sia da scienziati (prof. Lev Pitaevski), scittori (dott. Vittorio Messori), teologi (prof. Piotr Roszak) e gente di profonda Fede (come dott. Romano Cainelli, Giusi Cagol, Elia Serafini, Mariella e Marco Visintainer, Glorianna Frisinghelli, Alda Anastasi e tanti, tanti altri). Un ringraziamento speciale va alla Dr.ssa Mariateresa Lezzi Gorga, per avermi aperto alla bellezza delle immagini sulla Creazione. Il libro non sarebbe ultimato senza un'attenta lettura dalla parte del caro amico, Dr Luca Morlino.

E infine, i ringraziamenti più importanti vanno alle mia amata sposa, Maria, silenziosa e fedelissima in tutto questo che invento.



The Annunciation is the greatest mystery of the Faith. Two worlds, the physical and the Divine, came together in the Body of Christ. Unified, on the word of God. She was a pious girl who listened and believed. Hotel de Cluny, Paris, photo GK, 2003.

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